

Flexibility in project planning for managing design change in projects

Graduation Research Thesis

MSc Construction Management and Engineering

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EXECUTIVE SUMMARY

Nowadays, construction projects face cost overruns and delays on a regular basis, not being able to achieve the success standards expected. This is widely attributed to the fast changing and dynamic environment of construction projects. It is argued that the project management mostly used has a traditional and conservative approach which is incapable of dealing with contemporary projects and its constant changes, creating a growing need amidst practitioners to employ a flexible approach. Within the changes arising in projects the type being accredited as the one with most significant impact is design change. Thus, the purpose of this project will be the following:

“Provide an insight on how the implementation of flexibility in project planning helps manage design change causes.”

In order to achieve this objective a main research question was formulated and several sub research questions, which will guide the research process. For answering these questions, a mixed methods approach will be used, divided into two different main steps.

How can flexibility in the planning of projects help manage design changes in construction projects?

Subsequently, to support this main research question, the following sub-research questions are formulated:

SQ1: What is flexibility in project management?

SQ2: Which enablers are used to add flexibility in the planning of projects?

SQ3: What are the types, causes and effects of changes in construction projects?

SQ4: Does a relationship exist between flexible recourses and causes of design change in projects?

SQ5: How can these flexibility recourses be implemented into practice?

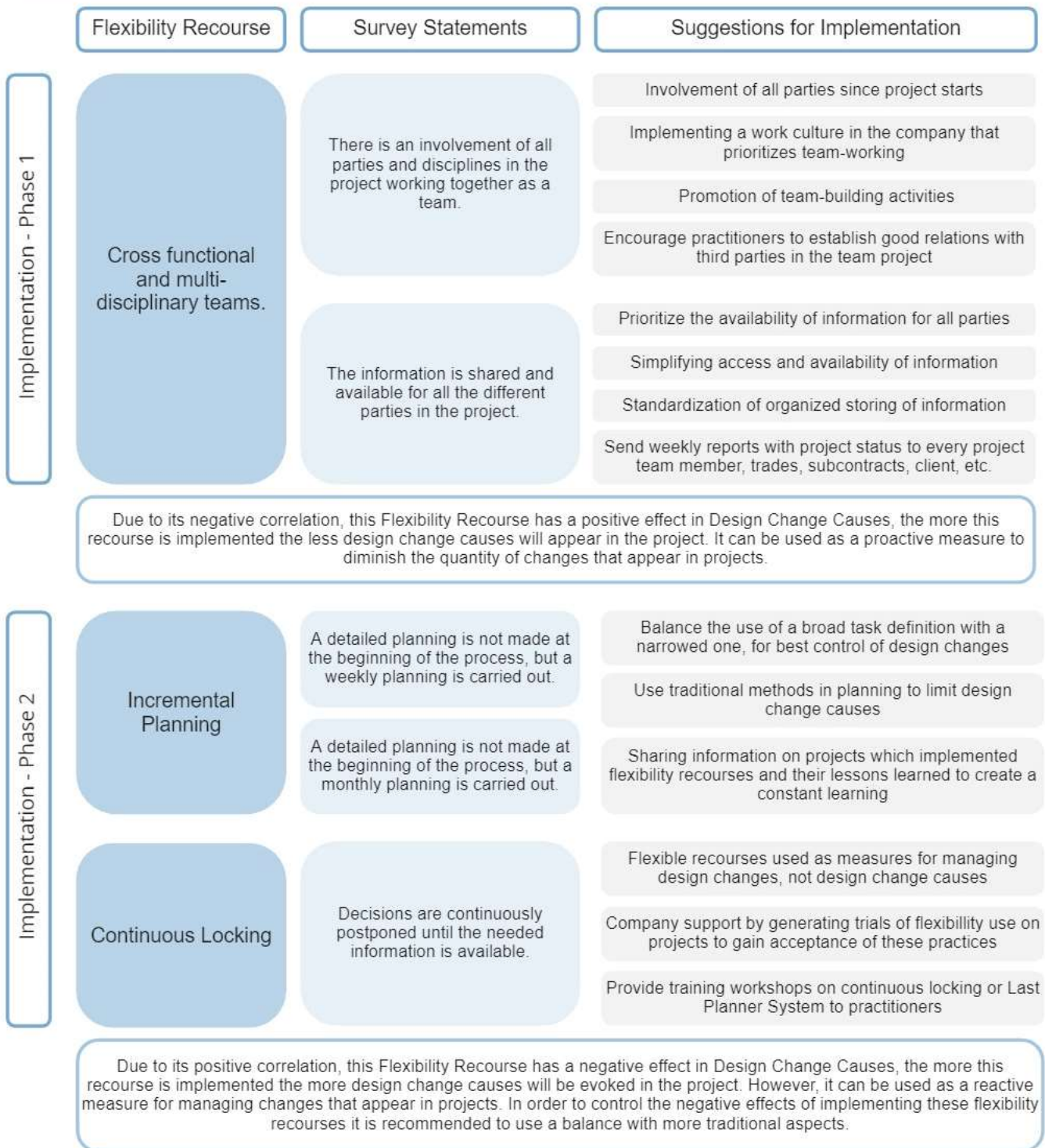
In the first step, qualitative research will be carried out to create a theoretical framework and answer the first three research sub-questions. Firstly, an extensive literature review is conducted to gather information on flexibility in project management and planning, and changes in construction projects. Following, exploratory interviews with DPR's practitioners is performed to complement the findings in the available literature. As a result of this first step the causes of design changes in projects will be established, as well as the different flexibility recourses to be used in the planning of projects. These two will act as the input for the next step.

Moreover, in the second step quantitative research will be conducted to analyse the relationship between the causes of design change and the flexibility recourses already established. These two will act as two sets of variables and a correlation analysis will be performed. For this to be possible, the causes of design change and flexibility recourses are translated into statements and assessed by the use of a survey. In total 115 responses were used for the correlation analysis.

Furthermore, from this correlation analysis 10 significant correlations were found which were comprised by 3 flexibility recourses. As well, some open questions in the survey introduced the mindset of respondents about flexibility and its practices. From all this, two main conclusions were established.

Firstly, the use of the flexibility recourse “cross functional and multi-disciplinary teams” helps to reduce the appearance of design change causes in projects. It is recommended to explore the different ways in which this recourse can be used and improve. In the Implementation Roadmap are some suggestions that can be implemented in a practical way. This flexibility recourse used in the planning helps managing design changes in construction projects by reducing their appearance. Secondly, the use of the flexibility recourse “incremental planning” and “continuous locking” does not help reduce the appearance of design change causes in projects but evokes them. However, the possibility of using these recourses to manage the design changes once they arise in projects is still viable. This flexibility recourse used in planning helps in managing design changes as a reactive measure.

Flexibility Recourses in Practice: the Implementation



1. INTRODUCTION

1.1 Research Context

The term Project Management, applied in the modern project management context, was used for the first time in the 1950's with an emphasis on scheduling, budgeting and controlling activities (Moses Jeremiah Barasa Kabeyi, 2019). However, the field of Project Management continues to evolve (Seymour & Hussein, 2014). Several organizations have established standards and guidelines which describe what project management is, as well as gathered best practices and tools to successfully manage projects (Nicholas & Steyn, 2017). These standardized guidelines or "best practices" focus in what is understood today by "Traditional Project Management" methodologies, which sets a practical application of tools and techniques to project activities within the project life cycle (initiation, planning, execution, monitoring and controlling, and closing (Institute., 2017). These set of tools and techniques aim to achieve project goals successfully, measured by The Iron Triangle: within desired time, cost and quality (Atkinson, 1999). Although some scholars support traditional project management practices (Giezen, 2012a, 2012b; Menches, Hanna, Nordheim, & Russell, 2008), others argue that traditional practices are predominantly control-focused methods (Eriksson, Larsson, & Pesämaa, 2017; Gustavsson & Hallin, 2014a; Pollack, 2007) with the aim of reducing the uncertainty and complexity in projects (Giezen, 2012b; Koppenjan, Veeneman, Voort, Ten Heuvelhof, & Leijten, 2011).

Nowadays, it is often observed that projects are faced with costs overruns and delays (Flyvbjerg, 2013), these have been associated to different causalities such as highly dynamic environment (Bosch-Rekvelde, 2011), increasing complexities (Hertogh & Westerveld, 2010), and unavoidable uncertainties (N. Olsson, 2006; Špundak, 2014) within the project. Notwithstanding the already available practices, traditional methodologies for project management are incapable of succeeding when dealing with dynamic environments (Augustine, Payne, Sencindiver, & Woodcock, 2005), creating the need to change from control-focused practices into flexibility-focused and adaptable management models which can cope with these dynamic environments (Joana Geraldi, 2008). Likewise, some studies state that not only a combination between control and flexibility are needed for the management of projects, but a balance between these two approaches (Koppenjan et al., 2011). These are reflected on the growing emphasis on developing flexible practices for the construction industry able to cope with changes and dynamics of contemporary projects (Jalali Sohi, 2018).

Flexible management is not a new concept (N. Olsson, 2006), it has been noted that the term is often used by practitioners but is rarely explored theoretically (Sager, 1990). Flexibility can be described as the means of making irreversible decisions reversible, or postponing these decisions until there is more information available (N. Olsson, 2006). Another way of defining project management flexibility can be as "the ability and readiness to deal with dynamics in a project" (Jalali Sohi, 2018). Furthermore, for this research flexibility will be understood as "the capability to respond to changing requirements" (Lim, Ling, & Ofori, 2007).

Flexible project management is a known topic among scholars, and its application presented successful results in other industries like IT. However, in the construction industry there has been a limited implementation of flexibility (Jalali Sohi, 2018), opening the possibility of developing its possibilities in this area. Furthermore, flexible project management has been stated to be the solution to coping with the changing requirements of projects, but there is still a need for understanding how to incorporate flexibility in the process, which is the core of this thesis.

1.2 Research Gap

Nowadays, projects are characterized by uncertainties which seem unavoidable (Bosch-Rekveltdt, 2011), these uncertainties create a highly dynamic environment which is subject to changes (Jalali Sohi, 2018). These changes are often associated with projects failing to reach a successful performance, or reduced efficiency in the process (N. Olsson, 2006). As well, scholars argue that changes in construction projects are inevitable (William Ibbs, Long D Nguyen, & Seulkee Lee, 2007a) and have detrimental effects on projects like delay, cost overrun and productivity degradation (Rashid Maqbool & Yahya Rashid, 2017). In construction projects, a change can be understood as “an alteration to design, building work, project program or other project aspects caused by modifications to preexisting conditions, assumptions or requirements” (Ming Sun & Meng, 2009). Construction projects are prone to a high degree of change during its lifecycle, and arise at different stages of projects (Ming Sun & Meng, 2009).

The management of changes in projects continues to be a real challenge (Lehmann, 2010) and its most frequent effects on projects are increases in cost and time (Ming Sun & Meng, 2009). A possible reason why the effects of changes are seen strongly in the planning of projects may be in the nature of how scheduling is done. Eizakshiri, Chan, and Emsley (2015) describe how project planners deal with the difficulty of planning activities on a desired future which is unintentionally biased given the dynamic nature of projects and how these develop over time. Thus, practices and tools from traditional projects management seem no longer effective for managing projects in a dynamic environment (Špundak, 2014). Likewise, Augustine et al. (2005) claims that traditional methodologies for management are incapable of succeeding when linear tasks do not aid with dynamic environments and schedules are in need of constant updating due to changes in the project.

The use of flexibility in projects is proposed by scholars as a way to embrace necessary changes that arise from uncertainty and dynamic environments (Aaker & Mascarenhas, 1984), establishing that flexibility as a strategy for managing changes can be applied in the product or in the process (N. Olsson, 2006). According to N. Olsson (2006) flexibility in the process is founded in a methodology in which decisions are made in a sequential manner, and describes flexibility as a tool for reversing decisions or delaying irreversible decisions.

Some methodologies and existent practices aim to add flexibility into traditional practices to help coping with the effects of these changes and dynamic environments in projects. Firstly, Goldratt (1997) states that one of the problems being

faced in the management of projects are time overruns due to uncertainty, and proposes to use his “Theory of Constraints” as a solution to these problems in project management by adding buffers to increase the flexibility within the schedule, which is commonly known as “Critical Chain Theory” (McKay & Morton, 1998). Secondly, some scholars explore the possibility of adding flexibility of resources in the schedule as a way of dealing with dynamics in projects successfully (Faria, Araújo, Demeulemeester, & Tereso, 2020; Lima, Tereso, & Faria, 2019). Moreover, Jalali Sohi (2018) researches how to implement flexibility in project management for improving project performance, and proposes different enablers for flexibility which encompass five categories: What, How, Who, When and Where. Within the “When” category enablers able to add flexibility to the definition and changes in time constraints are listed. Furthermore, Agile Management is gaining wide public attention due to its adaptability to changes during the project lifecycle (Špundak, 2014) bringing possible solutions for the dynamic environment projects are facing today. Although, some scholars claim that this methodology has big potential for design and pre-design phases, but carries substantial hurdles for implementing in construction phase (Owen, Koskela, Henrich, & Codinhoto, 2006). Additionally, other theories as Lean Construction is aimed for construction industry and uses the “last responsive moment” as a way to achieve flexibility in projects (N. Olsson, 2004). Nevertheless, Lean Construction has limitations regarding the dynamic environment in projects, since it is not able to cope with changes (Bertelsen, 2002).

However, the research has not explored when these flexible practices become useful to help coping with changes in projects. The literature has not explored how different types of flexible approaches can help manage different types of changes within projects. This leaves a gap in the research on implementation of flexibility in projects, which this thesis aims to address.

1.3 Problem Statement

Based on what was mentioned above, contemporary projects are embedded in a dynamic environment which traditional approaches are seemingly incapable of coping with. Subsequently, there is a growing need amidst practitioners to employ flexible approaches to projects as a way of achieving success (Priemus, Bosch-Rekvelde, & Giezen, 2013).

Several researchers agree on the necessity of flexibility to manage uncertainties in project management (Koppenjan et al., 2011; Olsson, 2006; Geraldi, 2008; Ossipova and Eriksson, 2013; Aaker & Mascarenhas, 1984; Jalali Sohi, 2018), yet there is hardly any research on how flexibility helps manage changes within projects. In addition, in the research by Padala, Maheswari, and Hirani (2020) it is argued that changes have significant impacts in projects, however the most frequent and costly type of changes are related to design changes. Likewise, Abdul-Rahman, Wang, and Yap (2015) and Hui, Abdul-Rahman, and Chen (2017) state in their research that impacts of design changes on project performance and establish that these changes are the ones with the most significant impact on cost overruns in projects around the world. Accordingly, this research presents the following problem statement to target that gap:

“Traditional project management appears to be incapable of managing design change in project planning.”

1.4 Research Objective

Based on the research context, the research gap and problem statement, the main objective of this research is as follows:

“Provide an insight on how the implementation of flexibility in project planning helps manage design change causes.”

1.5 Research Questions

To address this gap the research will try to answer the following main question:

How can flexibility in the planning of projects help manage design changes in construction projects?

Subsequently, to support this main research question, the following sub-research questions are formulated:

SQ1: What is flexibility in project management?

SQ2: Which enablers are used to add flexibility in the planning of projects?

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1.6 Scope

This research focuses on the time aspect within the planning of construction projects and how flexibility can be enabled in it to help manage design changes. The reasoning behind the planning of projects is due to the greater level of flexibility in this phase compared to others. The research will emphasize on planning flexibility and its potential as a way to help manage design changes in projects.

The research will be focused mainly on construction projects since is the main interest and type of project in DPR Construction, the company where this research will be held. The perspective will be the one of the company, a contractor

perspective. The outcomes of this research will be limited at the experience of the practitioners that are part of this company and the projects carried out by DPR Construction.

1.7 Relevance

An overview of the relevance of this research is presented in Figure 1.

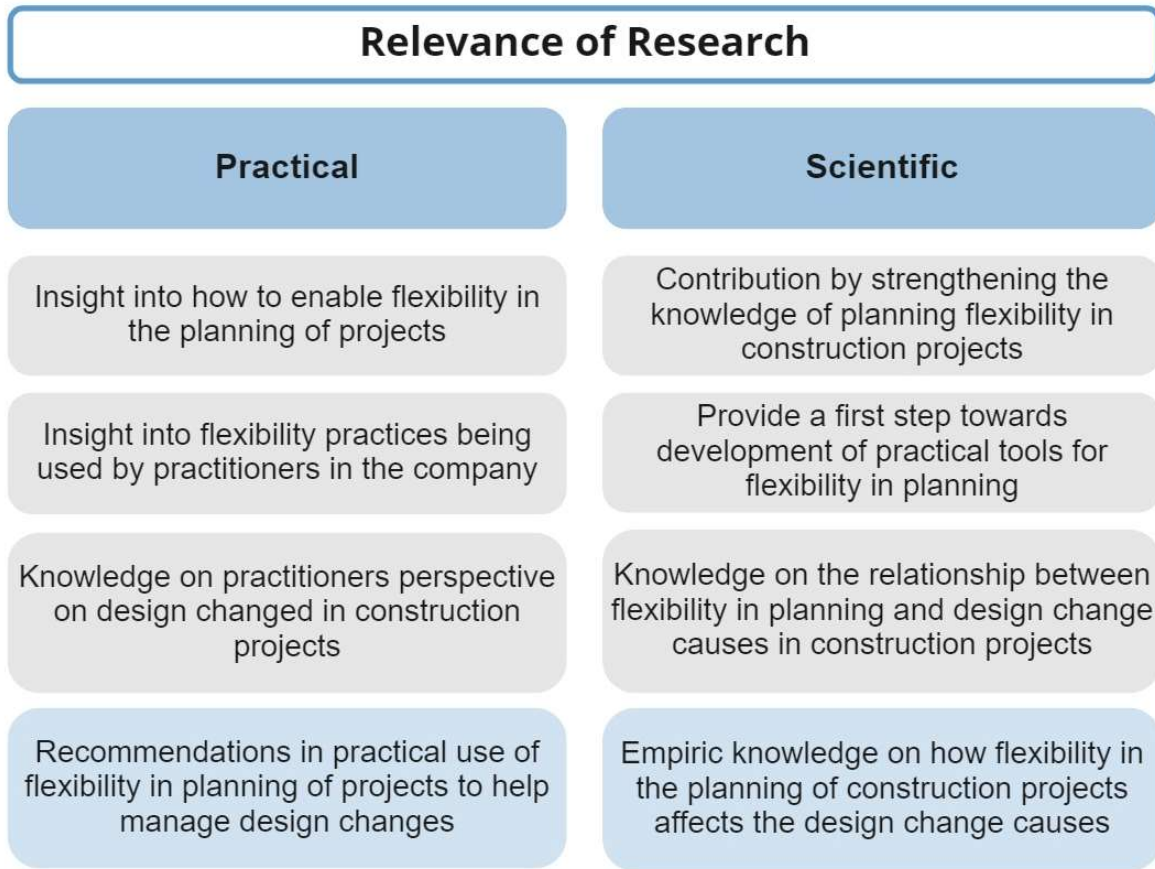


Figure 1 - Research Relevance

Practical

The results of this study aim to give some new insight into how the use of different flexibility enablers in the planning can help with managing design changes in projects. For achieving this, insights into the different flexibility enablers in planning will be discussed, an understanding of the flexibility practices that are (not) being used by the practitioners of the company and how could this be improved for managing design changes. As well, the research will give an exhaustive description on the different type of changes that construction projects are faced with, its causes and effects, based not only in the available literature but in the perception and insights of practitioners of DPR. As a result of the research

recommendations will be given into how the use of flexibility in planning can help manage design changes in construction projects. These recommendations will aid practitioners with decision – making and managing design changes, explaining when the different flexibility strategies should be used to help managing these changes.

Scientific

The research would contribute to science by providing new knowledge on flexibility in Project Management which supports the existing knowledge available in literature. As well, it will provide new knowledge on flexibility in the planning of construction projects which is a topic that has not been research deeply. In addition, it will develop a framework based in literature for strategies or practices which enable flexibility in the planning and scheduling of projects, this will contribute into the available knowledge on flexibility applied to planning of projects. Furthermore, it will provide empiric knowledge on how the use of flexibility in the planning of construction projects affects the design change causes. This information will analyse the relationships between flexibility and design change causes and analyse the capacity of flexibility to help managing design change and its causes in construction projects.

1.8 Methodology

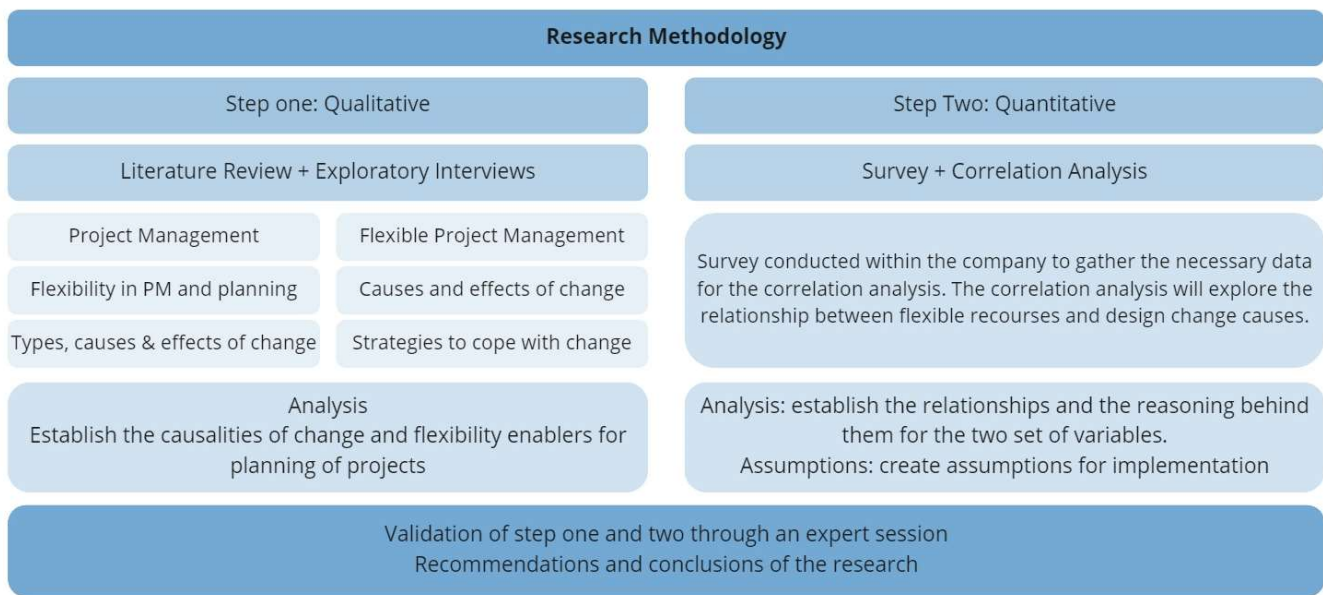


Figure 2 - Research Methodology

The research methodology will start by the creation of a theoretical framework as the base of the overall research. This theoretical framework will be constituted by an extensive literature review and exploratory interviews to practitioners from the company which as a way of complementing the findings. The literature review will create the clear view on traditional project management and the need for flexibility in project management. In order to answer the first three sub

research questions literature studies on the following topics will be carried out: Project Management, Flexibility in Project Management, Flexibility in Planning, Changes in Construction Projects, Types of Changes, Causes of Changes and Effects of Changes.

For answering the fourth sub-research question a study will be performed. For it a mixed methods approach will be used combining qualitative and quantitative forms, according to Creswell (2009) quantitative research is a means of testing objective theories researching the relationship between variables, while qualitative research is a way of exploring and understanding the meaning that is ascribed to a social problem. The decision of using a mixed methods approach was done since the research aims to find the relationship between of using flexibility enablers in the planning of projects and design changes causes, to understand if this relationship could help manage design changes in projects. For the study of this relationship between flexibility enablers in the planning and design change, it was decided to carry out a correlation analysis. Using this analysis information on the existence of the relationship, the strength, and the direction of it if existent will be obtained. A more elaborated explanation of correlation analysis can be found in chapter 3 which explains extensively this methodology. Moreover, the results of this study will be analyzed, and assumptions will be made about these relationships. These assumptions will be validated by experts through an expert session, where the last sub-research question will be answered. The outcome of this validation will be transformed into recommendations and conclusions of this research, and the main research question will be answered.

2. THEORETICAL FRAMEWORK

In this chapter the theoretical framework will be set up, the information will be gathered by the use of an extensive literature review and the use of explorative interviews with practitioners. Firstly, an introduction on Project Management and its development will be provided (2.1). Secondly, the concept of flexibility in Project Management will be introduced and explained (2.2). Next, it will be discussed the concept of flexibility in planning and scheduling (2.3) and the different strategies to add flexibility propose in literature (2.4). Following, the topic of changes in construction projects will be discussed (2.5) and the different types of changes will be explained (2.6). From these types of changes only one type of change, Design Changes, will be further explored (2.7) introducing the causes for this type of change (2.8) and its effects on projects (2.9) that are explained in literature. In the last sections of this chapter insights from practice on the topics of change, flexibility, and project management, gathered by explorative interviews, will be discussed (2.10). Rounding up with the conclusions of the entire chapter, giving response to sub-question 1 and sub-question 2 of this research thesis.

2.1 Project Management

What we know as Project Management nowadays, was used for the first time in the 1950's, and since then it has been extensively used in theory as in practice in several different fields, such as business, engineering and construction. It comprehends the use of standardized practices and tools, and its application in projects for its correct management (Lima et al., 2019). Project management is defined by Institute. (2017) as “the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements”. Other definitions do not vary significantly, Cockburn (2003) defines it as any principle management teams rely on to successfully deliver the project results. Similarly, Charvat (2003) defines it as a set of guidelines and principles which can be tailored for its application to specific situations, guidelines go from its simplest form of a task list to the most specific approach with defined techniques and tools.

After Project Management first appeared in the 1950's with the development of the Critical Path Method and PERT, significant development has taken place to continue improving the management of projects (M. J. B. Kabeyi, 2019). Project Management has been evolving since, and continues to evolve (Seymour & Hussein, 2014). Project Management has developed to adapt to changing requirements and project environment (Jalali Sohi, 2018).

The Project Management approach has an emphasis on scheduling, budgeting and controlling activities (M. J. B. Kabeyi, 2019). These activities have been established as standardized best practices and tools to successfully manage projects (Nicholas & Steyn, 2017). These standardized guidelines or “best practices” focus in what is understood today by “Traditional Project Management” methodologies, which sets a practical application of tools and techniques to project activities within the project life cycle (initiation, planning, execution, monitoring and controlling, and closing (Institute., 2017). The main idea behind this traditional, rational, and normative approach is that projects are quite simple, sequential,

and predictable, with defined boundaries and rather easy to plan in and follow that plan without changes (Collyer, Warren, Hemsley, & Stevens, 2010; Shenhar & Dvir, 2007; Špundak, 2014; Williams, 2005). Hence, this approach is characterized by planned activities and control methods, focusing extensively in front-end planning (Koppenjan et al., 2011). The main goal of traditional approach is optimization and efficiency in carrying the project plan (Shenhar & Dvir, 2007; Špundak, 2014), which leads to achieve project goals successfully, measured by The Iron Triangle: within desired time, cost and quality (Atkinson, 1999).

Nowadays, poor performance, such as delays and cost overruns, are commonly encountered in construction projects, and the reasons for these problems has engaged the attention of scholars (Sohi, Hertogh, Bosch-Rekveltdt, & Blom, 2016). These have been associated to causes such as highly dynamic environment (Bosch-Rekveltdt, 2011), increasing complexities (Hertogh & Westerveld, 2010), unavoidable uncertainties (N. Olsson, 2006; Špundak, 2014) and changes (Eriksson et al., 2017) within the project. Several scholars argue that traditional project management is not capable of succeeding when dealing with dynamic environments (Augustine et al., 2005). This is attributed to the linearity and hierarchy of the traditional approach, which is unable of dealing with complexities and dynamics in a satisfactory manner (Gustavsson & Hallin, 2014b; Pollack, 2007; Shahu, Pundir, & Ganapathy, 2012). The restrictions of traditional project management to manage current projects leaves these projects with delays and costs overruns affecting project performance (Collyer et al., 2010; Eriksson et al., 2017; Flyvbjerg, 2013). These creates the need to change from control-focused practices into flexibility-focused and adaptable project management models which can cope with these dynamic environments (Bosch-Rekveltdt, 2011; De Meyer, Loch, & Pich, 2002; Joana Geraldi, 2008; J. G. Geraldi, 2009; Giezen, 2012a). Likewise, scholars argue that not only the flexible focused approach is needed, but a balance between control and flexible approaches is needed for the management of projects (Joana Geraldi, 2008; Koppenjan et al., 2011).

Since the 1990's there has been a rising awareness on the changing and dynamic project environment (Bosch-Rekveltdt, 2011), leading to a wave of project management developments. A paradigm shift, from traditional project management towards an approach that is able to manage today's challenges, seems vital (Cooke-Davies, Cicmil, Crawford, & Richardson, 2007). Williams (2005) argues that traditional approaches to project management results inappropriate and likely have adverse effects in projects with these challenges. There has been a wide development of non-traditional approaches for project management in the last years and a growing emphasis on developing flexible practices for the construction industry able to cope with changes and dynamics of contemporary projects (Jalali Sohi, 2018). Examples of these are "Agile" or "Lean" which show promise for projects that are structurally complex or uncertain (Fernandez & Fernandez, 2008).

To summarize, due to the poor performance in today's projects, it seems apparent the need for change. Project Management calls for a transition from traditional approach towards an approach which can better deal with complexity and changing environments. An approach which has the right balance between control and flexibility to accommodate demanded changes (Joana Geraldi, 2008; Hertogh & Westerveld, 2010; Jalali Sohi, 2018; Koppenjan et al., 2011). The next

section describes what is meant by flexibility in project management, as a possible new approach to contemporary projects.

2.2 Flexibility in Project Management

The changing environment and increased project complexity demand greater flexibility in the approach for project management. As seen in the previous section, the need for flexibility has been greatly stressed in the literature. Hence, different scholars have researched different characteristics of flexibility, which try to understand the concept of flexibility in project management and its possible use in practice. In this section, it will be presented the different aspects of flexibility which arise in the literature for project management.

Flexibility in project management appears as a response to the dynamic environment, however flexibility management is not a new concept (N. Olsson, 2006). Kreiner (1995@) states that for dealing with changes and uncertainties in the changing business environment flexibility is demanded. As well, using a flexible approach when dealing with effects of uncertainty in planning was recommended by Sager (1990) who also established various examples of flexibility. Flexibility as a reaction to environmental uncertainty was established by N. Olsson (2006), since uncertainty challenges the strength of the traditional approach to project management (Kreiner, 1995). In Figure 3 can be appreciated different definitions for flexibility from different areas or focus.

One of the earliest definitions of flexibility is the one by Bateson (1972) which establishes that flexibility is the “uncommitted potentially for change”. Another definition for flexibility can be as a capability of the project manager, as J. R. Turner (2004) states “the project manager should be empowered with flexibility to deal with unforeseen circumstances as they see best, and with the owner giving guidance as to how they think the project should be best achieved” (Jalali Sohi, Bosch-Rekvelde, & Hertogh, 2020). N. Olsson (2006) describes it as a way of making irreversible decisions more reversible, or postponing irreversible decisions until more information is available (Jalali Sohi, 2018). As a way to increase flexibility, Perminova, Gustafsson, and Wikström (2008) concludes that reflective learning and sensemaking are needed. These are key elements for managing and decreasing, to some degree, uncertainty in projects. Yet, some uncertainty is wanted to maximize opportunities (Jalali Sohi, 2018).

Another aspect of flexibility, and one of its crucial concerns, is keeping the options open (Sager, 1990). This is described in project management as the use of strategic flexibility (Ford & Bhargava, 2006). Ford and Bhargava (2006) argue that flexible project strategies in the form of options can strongly influence performance and increase project value. The aim

	DEFINITION	AREA	SOURCE
01	"the capability to adjust the project to prospective consequences of uncertain circumstances within the context of the project"	General Project Management	Husby et al. (1999)
02	"the ability to adapt , in a reversible manner, to an existing situation, as opposed to evolution, which is irreversible"	Organizational Flexibility	Bucki and Pesqueux (2000)
03	"ability to cope quickly with changing circumstances and environmental uncertainty "	Process Flexibility	Gupta and Goyal (1989)
04	"ability of a system to quickly adjust or adapt to any changes in relevant factors"	Process Flexibility	Nagarur (1992)
05	"the ability to change or react with little penalty in time, effort, cost or performance"	Economical Flexibility	Upton (1995)
06	"the ability to meet an increasing variety of customer expectation without excessive costs, time, organization disruptions or performance losses"	Organizational Flexibility	Zhang, Vonderembse, and Lim (2003)
07	"Flexibility, in turn, is about adapting to uncertain and rapidly-occurring environmental changes that might affect the organization's performance"	General Project Management	Ossipova and Eriksson (2013)
08	"capabilities that quickly adapt the system in response to the effects of changes, without inflicting damage to production goals"	General Project Management	de Miranda Filho, da Costa, and Heineck (2012)
09	"flexibility is commonly defined as the ability to respond effectively and efficiently to changing circumstances "	Process Flexibility	Schmenner and Tatikonda (2005)
10	"degree to which an organization possesses a variety of actual and potential procedures , and the rapidity by which it can implement these procedures, in order to increase the control capability of the management and improve the controllability of the organization and the environment "	Organizational Flexibility	De Leeuw and Volberda (1996)

Figure 3 - Definitions of Flexibility from literature

is to expand the control of planners and managers by increasing the number of possible scenarios by applying real options approach into the planning (Ford, Lander, & Voyer, 2002). Flexibility is also used for investment decisions since these are characterized by being uncertain and irreversible (Huchzermeier & Loch, 2001).

Aaker and Mascarenhas (1984) states that while control as an approach aims at reducing undesirable changes, flexibility aims to incorporate changes as a way to adapt to the uncertain and changing environment. Koppenjan et al. (2011) defines two approaches to control and flexibility depending in the attitude towards the management of uncertainty and complexity. On the one hand, “command-and-control” aims at eliminating uncertainty and complexity by focusing on strict planning and control over the process. On the other hand, “prepare-and-commit” aims at managing uncertainty and complexity by close cooperation between actors (Koppenjan et al., 2011), which increases flexibility (Jalali Sohi, 2018).

Furthermore, some researches were based in case studies, N. Olsson (2006) states that even though flexibility was frequently needed in the different projects studied, the projects were rarely prepared for it. N. Olsson (2006) recognizes two different types of flexibility in project management: “process flexibility” and “product flexibility”. About flexibility in the process, it is defined as the adaptability to decision making, so as to respond to uncertainty. While product flexibility refers to the adaptability in the use of project deliverables. N. Olsson (2006) proposes three strategies to achieve flexibility in decision process. Firstly, ‘late locking’ of concepts, specifications, and organizations. Secondly, ‘continuous step-by-step locking’ by committing successively to projects by the use of decision gates or by incremental decision making (N. Olsson, 2006; Pundir, Ganapathy, & Sambandam, 2008). Thirdly, ‘contingency planning’ where plans are defined, but an alternative set of plans can be put into place if needed (Pundir et al., 2008).

These two types of flexibility, “process flexibility” and “product flexibility”, interact within a project. The interaction is given by the proportion (high or low) of each type of flexibility, creating four different environments. N. Olsson (2006) proposes different strategies for each environment to be able to manage them, this can be seen in Figure 4.

After this last section, it can be observed a description of the concept of flexibility and different meanings extracted from the literature with focus in different areas. It has been discussed aspects as planning flexibility, strategic flexibility, decision-making flexibility, product flexibility and process flexibility. Moreover, in the different definitions for flexibility it can be seen a double commonality between them, which refers to uncertainty due to dynamic environments and the ability to respond expeditiously to changes. From these definitions we can conclude an overall definition for flexibility: “ability to expeditiously react to the dynamic environment”. Consequently, for this research, it will be the used a similar definition for flexibility in project management by Jalali Sohi (2018) “the ability and readiness to deal with dynamics in a project” (Jalali Sohi, 2018). Furthermore, in the next section it will be explained further the concept of flexibility focused on planning and scheduling process in projects.

2.3 Flexibility in Planning and Scheduling

This section will discuss how the concept of flexibility regarding planning is explained in literature. As well some recommendations from literature to achieve flexibility in planning or the schedule will be analysed.

In project management, since its formal recognition as a practice in the 1950's, the planning of projects and the scheduling have been considered as the basis of in project management of construction projects (Dvir & Lechler, 2004). Atkinson, Crawford, and Ward (2006) argue that usual interpretation of project planning is an attempt to define a wilful future. They establish that it creates a set of reasonable assumptions as the base to move the project forwards (Atkinson et al., 2006). The Project Management Body of Knowledge states 'planning' as the processes which establish the scope of the project, defines, and refines the objectives and designs the course of action to reach these goals. The planning explores all aspects of the project as scope, time, costs, quality, communications, risk, procurement, etc. (Institute., 2017). Meanwhile the 'scheduling' is more than just adding tasks in a Gantt chart, it is an integral part of the project planning (Nicholas & Steyn, 2017). The scheduling concerns the activities, durations and resources for the project (Institute., 2017). As explained by Nicholas and Steyn (2017) the scheduling process "shows how to get where you want to go, but also progress you have made along the way" (Nicholas & Steyn, 2017).

Most project management tools, which are based on traditional practices, tend to be control oriented. There is an emphasis in hierarchical structures and a centralized decision making, division of work and responsibilities (Lenfle & Loch, 2010). Traditional project management practices are expected to follow a sequential highly detailed plan for the entire

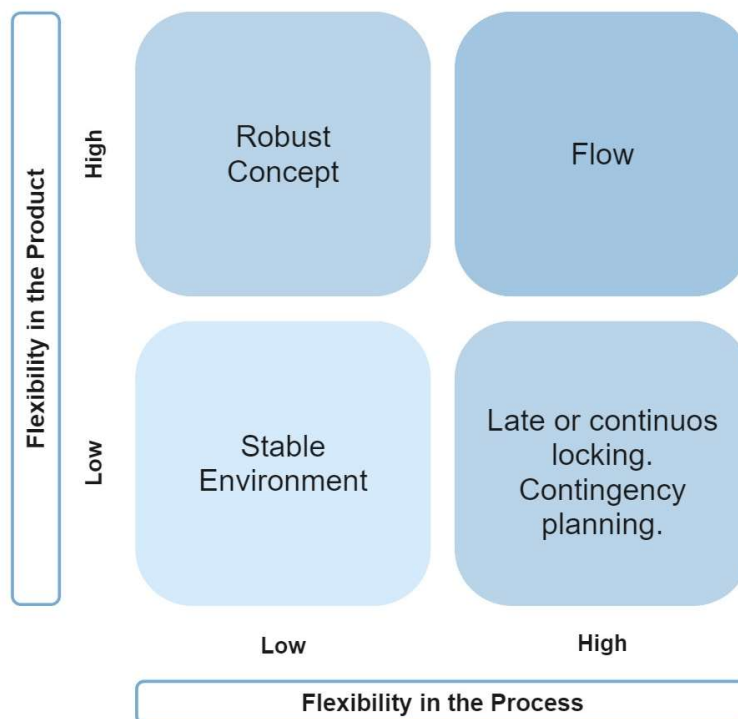


Figure 4 - Interaction of Process Flexibility and Product Flexibility, adapted from N. Olsson (2006)

project, which needs to be followed unchangeably (Owen et al., 2006). Deviation from this plan is not acceptable and should be resolved to get back on plan as soon as possible. This focus on control has as a drawback the hampering of collaboration and adaptability (Osipova & Eriksson, 2013). Besides, even though these tools have evolved to cope with an out-of-control world, they tend to fail when linear tasks do not assist with dynamic processes and when schedules need constant updating due to changing environments (Augustine et al., 2005). Therefore, Joana Geraldi (2008) argues that to be able to manage uncertainty and complexity in projects there is a need for flexibility. Additionally, the findings of Szentes and Eriksson (2016) support the need to complement practices like planning, scheduling and supervisory aspects, which traditionally have a substantial focus on control, with an explicit focus on flexibility. A large number of authors agree to the need of a shift in paradigm, from a rigid and formal planning and scheduling towards a flexible one, that is able to cope and adapt to changing situations (N. O. Olsson & Hansen, 2010). As well, Giezen (2012a) concluded that an adaptation is called for in planning and decision making of complex projects, to be able to handle the unexpected changes. The majority of project managers acknowledge the necessity to follow a structured plan when managing projects, and the ensuing fight to get back to plan when changes arise (Owen et al., 2006). Regardless, adopting flexibility in planning and scheduling in projects does not imply that current practices and tools should not be used. It implies an adaptation of these tools to meet the project needs and requirements to be able to cope with changes and the uncertainty in the dynamic environment (Mahmoud-Jouini, Midler, & Garel, 2004).

Flexibility in the planning phase of projects can be accomplished besides making flexible decisions, by having possibilities of adjustment in the complete planning, being departing from it, changing it or side-stepping it (Sager, 1990). Consequently, Sager (1990) proposes some ways for achieving flexibility in the planning and scheduling. Sager (1990) explains that, firstly, by avoiding specifying determined steps in the schedule when this is dependable on information that is not available at the moment, or will be defined in the future, one can increase the flexibility in plans and schedules. Secondly, another possibility would be to avoid taking decisions in earlier stages which are unnecessary and will limit the possible scenarios in the future (Sager, 1990). Both of these tools are manoeuvres which make the plan and schedule flexible. According to Sager (1990), the planning of a project can be flexible when keeping options open. Similarly, Ford et al. (2002) establishes that a way to expand the control of project managers on the planning is by increasing the number of scenarios available. They argue that dynamic uncertainties are difficult to incorporate into planning since the knowledge needed about future conditions is not available. However, they propose the use of a real options approach for the planning of construction projects and its potential benefits (Ford et al., 2002). A real option is defined as the right without the obligation to take action, depending on how the uncertain future conditions evolve (Amram & Kulatilaka, 1998).

Other industries have confronted similar problems in their projects, having to adapt the traditional management approach to new ones. This is the case of Agile Management (see Appendix A), which started in the Software Industry at the beginning of the 2000's as a response for the changing and dynamic environment in projects (Cooke, 2012). Stare (2013) argues that agile management and its practices are essential for project success in the 21st century. In the last

years Agile Management has been spreading to other industries including construction. Scholars argue that some characteristics of the most known practice within Agile, Scrum, includes several elements which create the flexibility needed in contemporary projects. These elements are iterative and incremental planning and short cycles of feedback loops (Stare, 2013). Additionally, strategic decisions are delayed as much as possible, increasing the ability to respond to feedback (Takeuchi & Nonaka, 1986). The use of daily meetings as a way to monitor and control the progress of the project, helps detect problems and changes as soon as possible (Koskela & Howell, 2002). These meetings become even more useful for coordination of changes since the whole team shall be present, and the team is characterized by being a cross functional team. Scrum process has into account the changes that arise in projects and manages them by the use of the elements mentioned. Changes are seen as a way to add value to the project, so its management will turn primordial for this practice (Owen et al., 2006).

Joana Geraldi (2008) proposes six parameters to characterize the flexibility involved in projects, these are: What, How, Who, When, How Much, Where. The parameter “When” is the parameter that is more related to the planning phase of a project, since this will be defined as “the ability to define and change when the tasks should be realized” (Joana Geraldi, 2008). This comprises the changes in plans and schedules, including milestone definition and changes in priorities within the project. Similarly, Jalali Sohi (2018) investigates the enablers of flexibility in project management, defining five categories of flexibility enablers: What, How, Who, When and Where. The category of “When” is defined as the “ability to define and change the time constraints for different tasks (schedule flexibility)” (Jalali Sohi, 2018). In his research he establishes five enablers for the “When” category, being: late locking, short feedback loops, continuous locking (iterative), Iterative planning, iterative delivery (Jalali Sohi et al., 2020).

Furthermore, G. Ballard and Vaagen (2017) argues that a flexible strategy, besides being able to adapting to changes, must anticipate and rapidly respond to these changes. In their research they propose two possible strategies for adding flexibility in the planning of the project: “postponement” and “hedging” (G. Ballard & Vaagen, 2017). “Postponement” refers to postponing decisions until information becomes available and/or when it is feasible to update these decisions with new relevant information. On the other hand, “Hedging” refers to the development or purchase of an “insurance” which offsets potential losses (G. Ballard & Vaagen, 2017). Likewise, G. Ballard, Vaagen, Kay, Stevens, and Pereira (2020) claims that postponement of decisions and buffering systems used in the Last Planner System have shown promise to handle changes in projects, since constant adaptation to new information or changes is implicit in this tool. The Last Planner System is a tool within Lean Management (see Appendix B), lean thinking has been described as the management of dynamic projects (Howell & Ballard, 1998) and its principles assist with producing solutions for changing conditions in projects (Vaagen & Ballard, 2021). The Last Planner System is the best known technique within Lean Production Management and has been proved highly useful for managing projects (AlSehaimi, Fazenda, & Koskela, 2014). This tool is used for planning, monitoring and controlling projects, using a collaborative planning and making the plan more detailed as it gets closer to the execution phase (Porwal, Fernández-Solís, Lavy, & Rybkowski, 2010). The collaborative planning environment promotes exchange and continuous resolution of constraints, increasing efficiency in workflow and accurate

strategies for buffering (G. Ballard et al., 2020). Kalsaas (2012) explains how the Last Planner System supposes that decisions in planning must be taken at the last possible moment as a way to avoid uncertainty in the predictions to be made. As well, aspects as phase planning, lookahead plan and weekly work plan are steps of the implementation of the Last Planner System which induce flexibility within the planning of projects (see Appendix B).

Besides this, some practices intent to give solutions for the fallouts of traditional planning of projects. This is the case of Critical Chain Theory which has a focus on schedule of projects (Leach, 1999), which removes the hidden safety in the duration of tasks and adds buffers in “key points” to absorb possible delays (Long & Ohsato, 2008). There are three types of buffers: feeding, resource and project. Critical Chain Theory adds flexibility in the planning in the form of options, since the buffers are consumed only, if necessary, it becomes an option to use them. The reasoning behind Critical Chain is based in the estimation of task duration which is done on the 95% likelihood of completion, and that it should be reduced to 50% and the difference allocated in project buffers (Raz, Barnes, & Dvir, 2003). This is done since the safety margins will not be needed to finish the task, and probably will be completed sooner. Since the safety margins belong to each task if they are not used, they will be lost. By creating buffers any activity can end up using this safety times, creating more options in the planning, thus adding flexibility into it. Extended information on Critical Chain Theory can be found in Appendix C.

The ability to implement and incorporate flexibility into the process of the project depends on two features. Firstly, the ability to be flexible by the project management team or organization. Secondly, the commitment that this team or organization has to be flexible (N. O. Olsson & Hansen, 2010). In the next section different recourses which add flexibility in the planning and the schedule taken from the extensive literature study will be determined.

2.4 Flexibility Recourses from Literature

As established previously in this chapter, today’s construction projects are filled with uncertainties due to the characteristic dynamic environment (Williams, 2005). Therefore, several scholars argue that traditional project management is no longer effective to manage projects, practices and tools are not capable of succeeding when confronted to dynamic environments (Joana Geraldi, 2008). As a solution to overcome this, scholars proposed the use of flexibility in project management. Although not much literature researches the latter, evidence exists that some methodologies and tools are characterized by flexibility (Jalali Sohi, 2018). Thus, in this section different recourses taken out of literature which help add flexibility in planning and scheduling are established.

These recourses extracted from literature are: Incremental planning, Iterative Planning, Continuous Locking, Contingency Planning, Buffers, Late Locking, Short Feedback Loops, and Cross Functional and Multi-disciplinary Teams; these can be observed in Figure 5.

Based on the interpretation by G. Ballard and Vaagen (2017), “Late locking” refers to making certain decisions, or not fixing certain aspects, until later or the last possible moment before this becomes a problem (postponing decisions until last responsible moment) and not making decisions upfront before the availability of necessary information.

In his research, Jalali Sohi et al. (2020) explains “Continuous locking” as the process of continuously postponing taking decisions until the last responsible moment, without fixing these decisions in early phases or before the needed information is available. “Short feedback loops” describes the process of having team meetings in a continuous manner and giving feedback frequently on the activities taking place, these helps keeping the focus on the project objectives.

Furthermore, “Iterative planning” is the process of adapting the plan as the project advances, adjusting the schedule when it is needed in order to fulfil the requirements of the project Stare (2013). And Kalsaas (2012) mentions that “Incremental planning” is the lack of definition for the planning at the beginning of the project, and in a weekly or monthly basis a more detailed plan is done throughout the duration of the project.

Similarly, as explained by Long and Ohsato (2008) “Buffers” are describe as float or slack at the end of the project or after activities which influence the critical path, working as spare time to avoid delays. The time for these buffers is taken out of the duration of tasks which are shortened to allocate that time as buffers.



Figure 5 - Recourses of Flexibility in planning from Literature

For the recourse “Contingency planning”, the definition for it in this research will refer to: the creation of different options within the planning and project schedule (Ford et al., 2002).

Finally, the definition for “Cross functional and multidisciplinary teams” for this research is mainly based in Owen et al. (2006) who establishes that the creation of teams which involve multiple disciplines are able to create innovative solutions on a continuous manner, which helps creating more flexible teams with flexible solutions. As well is based partially in Kalsaas (2012) by adding the involvement of all parties in the decision making and enabling the availability and sharing of information between all the parties in the project. Thus, “cross functional and multidisciplinary teams” refers to the involvement of all parties and disciplines on the project working together as a team, having all parties the information on the project available for them.

These different recourses for flexibility are the base for the future steps within this research, creating one of the set of variables to be analysed. In the next section the concept of changes in projects will be introduced, so as to be able to understand the topic fully and analyse the relationship between flexibility recourses and changes. The concept of change, the types of changes found in literature and the reasoning behind the decision of which type to focus on will be discussed in further sections.

2.5 Changes in Projects

Today’s projects are inherently uncertain, becoming prone to unexpected events (De Meyer et al., 2002; Joana Geraldi, Lee-Kelley, & Kutsch, 2010; Huchzermeier & Loch, 2001; Ming Sun & Meng, 2009). In the research by Ming Sun, Fleming, Senaratne, and Motawa (2006) it is stated that in construction projects many decisions must be made under uncertain conditions. Different parties within projects need to base themselves in available information to make assumptions for the future, which may be proven incorrect in the later stages, needing to be revised and changes made on certain aspects (Ming Sun et al., 2006). This uncertainty has led to changes being extremely common in construction projects, and likely to occur at any stage of the project (Gokulkarthi & Gowrishankar, 2015). Comparably, in the literature by Hanna, Camlic, Peterson, and Nordheim (2002), it is attributed to the inherent uniqueness of projects and its limited resources of time and money, the inevitableness of changes within projects. The need for changes in construction projects has been described as a “practical reality” by Keane, Sertyesilisik, and Ross (2010), in their research they emphasize that no matter how much planning has been made for the project it may still need changes for different factors (Keane et al., 2010).

Changes tend to increase cost and time of projects, sometimes even to a considerable portion of the ones established by the contract (Chang, Shih, & Choo, 2011). These can have as a consequence delays in the completion of the works, as well as overspending or quality defects (Ming Sun & Meng, 2009). Durdyev and Hosseini (2019) raise concern about how completion of a project within the stipulated time is one of the critical success factors for projects, and delays in today’s projects have become a chronic problem worldwide. These problems besetting the project delivery process creates an

overall dissatisfaction from clients towards contractors, consultants, etc. (Ming Sun et al., 2006). This dissatisfaction makes the occurrence of changes and its impacts on project success a great concern for all parties in projects (Almasi, Moradianmina, & Zavari, 2011). Similarly, Memon, Rahman, and Hasan (2014) claim that changes in the construction phase are one of the major problems faced in construction projects, since these result not only in delays, cost overruns and causes dissatisfactions among the parties, but it is often the cause of disputes between the different parties involved in the project.

As stated by Cambridge Advanced Learner's Dictionary (Walter, 2008) change is to "make or become different, or to exchange to one thing for another thing, especially of a similar type" (Rashid Maqbool & Yahya Rashid, 2017). Nevertheless, in construction projects a change refers to "an alteration to design, building work, project program or other project aspects caused by modifications to pre-existing conditions, assumptions or requirements" (Ming Sun & Meng, 2009). Likewise, Hanna et al. (2002) and Gokulkarthi and Gowrishankar (2015) define change as "any event that results in modification of the original scope, execution time, or cost of work". In addition, Padala et al. (2020) argue that any additions, deletions or modifications to goal or scope, are considered changes no matter if they decrease or increase the duration or cost of a project. Furthermore, some scholars in their research refer to changes as variations. Nonetheless, variation is defined as "any type of deviation from an agreed upon, well defined scope or schedule of works" (Keane et al., 2010). The term variation, and variation order, is often used interchangeably with change, and change order (Hansen, Rostiyanti, & Rif'at, 2020). This research will not be an exception for this.

Once the change presents itself and its existence acknowledged by the project team, the next step is to formally regularize the change by the issuance of a change order (Alnuaimi, Taha, Al Mohsin, & Al-Harhi, 2010; Khalifa & Mahamid, 2019). A change order is a document which describes the scope of the change and alters the original contract (Hansen et al., 2020), the alterations are the impacts of the change on cost and/or time (Khalifa & Mahamid, 2019). Gokulkarthi and Gowrishankar (2015) defines it as "a written order to the contractor, signed by the owner, and issued after execution of the contract, authorizing a change in the work or an adjustment in the contract sum or the contract time". For this research, the terms change, change orders and variations will be searched in literature. However, as a way of establishing a coherence within the extent of the research it will be used the term "change".

To summarize, changes are very common in construction projects, and are likely to occur at any stage of the project. Most of these changes, if not managed properly will have considerable impact on productivity, disrupting work and its orderly sequence, causing delays and cost overruns (Anees, Mohamed, & Abdel Razek, 2013). Commonly, risk management tries to prevent uncertainty from materializing in projects, by creating strategies to contain its effects if they cannot be avoided (Joana Geraldi et al., 2010). However, Joana Geraldi et al. (2010) claims that this approach is dangerous and quotes: "(...) the danger is that continual advances in proactive management techniques will produce an over-reliance upon strategies of anticipation and deflect attention from the need to build resilience into organizations to deal with the unexpected" (Joana Geraldi et al., 2010). Hence, managing changes effectively is critical for the success of construction projects (Almasi

et al., 2011; Anees et al., 2013). In order to manage changes proactively, Padala et al. (2020) argue that understanding change causes and effects can support project teams with this. Similarly, Charkhakan and Heravi (2012) states that the proper identification and assessment of changes is an important tool for change management. Therefore, in the next sections the types, causes and effects of changes will be profoundly explored.

2.6 Types of Changes

The literature available on changes offers several possible classifications of changes, as explained by Charkhakan and Heravi (2012) change is a complicated concept, so as to facilitate its understanding different authors break the topic into tangible elements. This is done by selecting a factor of classification for changes, which could be change sources, change drivers, change causes, change requesters or responsible actor, change affected project parties, etc. (Charkhakan & Heravi, 2012). Following an analysis of different categories of changes will be established, based on the literature of several scholars and different factors.

Firstly, according to Ming Sun et al. (2006) the type of change can be determined on the degree of severity: “gradual change” or “radical change”. Gradual changes, or incremental, are those which happen over a period with a low intensity, they often occur in design phase when decisions have not been taken yet. While a radical change tends to be sudden, appearing after design phase and in execution phase, with a marked effect (Ming Sun et al., 2006). A secondary categorization relates to the possibility to predict the change, being “anticipated change” discovered before they occur, or “emergent changes”, which arise spontaneously during the project (Motawa, Anumba, Lee, & Peña-Mora, 2007; M Sun et al., 2004). Another way of seeing changes is based on necessity, these can be classified as “elective changes” and “required changes” (Ming Sun et al., 2006), “avoidable changes” or “unavoidable changes” (Almasi et al., 2011), as well as “preferential” or “regulatory” (Motawa et al., 2007). Changes can be classified by when the changes appear as “design development changes” and “construction changes”, the latter is more disruptive to the project development since the design is fixed (Ming Sun et al., 2006). A similar classification is proposed by Motawa et al. (2007) which states that changes can be determined based on its effect, they can be “beneficial changes”, “neutral changes” and “disruptive changes”. Changes can also be categorized as “proactive changes” and “reactive changes” (Motawa et al., 2007). Additionally, some scholars argue that changes can be considered “documented changes” or “un-documented changes” based if the changes are recorded in change orders (Almasi et al., 2011). A different type of change proposed by Almasi et al. (2011) can be “constructive changes”, modifications of contract due to defects or poor specifications, or “directed change”, directly imposed by owner. Another alternative by Dvir and Lechler (2004) can be “plan changes” or “goal changes”, being plan changes unintentional imposed by environment changes while goal changes are conscious decisions and modify the goals of the project (Almasi et al., 2011). In the research by Almasi et al. (2011) after conducting a comprehensive literature review and interviews with experienced project managers, it was identified a set of ten types of changes in projects. These are explained further in Figure 7.

Since the study of all these types of changes, its causes and effects would be too large a scope for this research, a decision on which type of change is going to be studied must be taken. For this, explorative interviews were carried out to gather some insights from practice. Considering the information gathered from practitioners and the classifications explained above, it can be said that the changes to be studied are within the categories of radical changes, since the effect in projects is major and tend to appear in execution phase, as the main examples pointed out by practitioners. Moreover, the study will focus on emergent changes, these changes occur spontaneously, thus, they have a disruptive effect on the project, and construction changes, since many decisions are already fixed the changes have greater impact on project. As well as changes which are required and unavoidable, from the perspective of the practitioners of DPR Construction since the effects of these changes tend to be greater and detrimental.

Based on the main categorization by Almasi et al. (2011) the change factor in which the research will be based is the Project Design factor. The reason behind it lies on the information gathered during the exploratory interviews carried out. The interviewees were practitioners in charge of the planning tasks of different projects within DPR Construction. The analysis of the interviews reflected the importance of design changes, not only for the frequency that they appear in projects, but as well their disruptive nature. Apart from the fact interviewees emphasized design change as the most

Types of Changes		
	Change Factor	Description
01	Project Location	Geographical change of project location due to technical constraints, environmental issues, etc.
02	Project Objectives	Any changes in project goal or objectives
03	Project Scope	Any reduction or expansion in project scope
04	Project Stakeholders	Changes of any parties involved such as project manager, owner, contractor, etc.
05	Contract Terms	Changes in project contracts terms and conditions.
06	Technology	Any changes occur in construction, design, testing or acceptance technologies.
07	Project Schedule	Any changes in project schedule such as adding new activities, changes in duration or sequence, or change in total duration.
08	Project Cost	Any changes in project budget or activities' cost due to any reason such as foreign currency changes.
09	Project Resources	Changes in resources such as material, human resources, financial resources, etc.
10	Project Design	Changes in project design, drawings, equipment specifications.

Figure 6 - Type of changes adapted from Almasi et al. (2011).

disadvantageous type of change, scholars have emphasized in different studies the importance of this type of change. Scholars claim that the main causes of change derives from design activities (Ming Sun et al., 2006). Furthermore, Memon et al. (2014) argues that design changes lies within the most significant type of changes, and in the study by Hsieh, Lu, and Wu (2004) it is concluded that the major part of change orders are due to problems in design. Consequently, the scope of this research will be focused on design changes in projects. This will add value to the research from the company's perspective and create more comprehensive conclusions for this thesis. In the next section design changes will be explored further, defining this type of change, and understanding its importance based on scholars' research.

2.7 Design Change

The scope of this research, as explained in the past section, focuses in only one type of change: Design Change. This is due to the fact that an extension to more type of changes would not be possible within the time frame of this graduation thesis. In this section, it will be explained what is understood by design changes from literature, as well as summarizing the importance of these type of changes and its relevance in literature.

Design changes in building construction projects are defined by Hui et al. (2017) as "design deviances with regards to the design requirements of the project" (Hui et al., 2017). As well, Yap, Abdul-Rahman, and Wang (2016) define design changes as "regular additions, omissions and adjustments to both design and construction of work in a building construction project that occurs after the award of a contract which affects the contract provisions and works conditions that make building construction dynamic and unstable" (Yap et al., 2016).

These design changes tend to have a significant impact in construction projects, scholars claim that the most costly and frequent observed changes are related to design changes (Padala et al., 2020). In their study, Abdul-Rahman et al. (2015) they research the impacts of design changes to project performance, and determined that these changes are the ones with most significant impact on cost overruns in developed and developing countries in the world (Hui et al., 2017) claiming up to 5 and 40% of the project cost (Aslam, Baffoe-Twum, & Saleem, 2019). Similarly, Aslam et al. (2019) argues that design changes being the greater contributors to cost overruns in projects is a well-known fact, and its effects are not specific to only one country or project. As possible causalities for these changes in projects Peter ED Love and Sing (2013) claim that is due to poor communication and lack of coordination between project team members. In addition, another causality mentioned in literature is the isolation of the design phase from the construction phase, which makes inevitable the existence of design changes in projects (Aslam et al., 2019). Furthermore authors as Chang et al. (2011) and Peter ED Love (2002) state that design changes tend to have as results rework in construction projects, understanding rework as "the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time" (Chang et al., 2011).

The emphasis on this type of change in construction projects found in literature, combined to the insights gathered from the practice, results in the election of design change as the focus for this research. For a greater understanding of what design changes are, it is necessary to understand which are the causes of this type of change and their effects on projects. This will be explained further in the next sections.

2.8 Causes of Design Changes

Changes occur for many different reasons (Memon et al., 2014), these reasons are entitled in the work of different scholars as change causes, sources or drivers (Almasi et al., 2011). The causes of changes and their effects in projects are complex and are influenced by several interrelated factors (Anees et al., 2013). Ming Sun and Meng (2009) define causes of change as “conditions or events that either directly trigger or contribute to a change in construction projects”.

The causes of changes found in literature are plenty, one of the views which is shared by a substantial number of scholars is the division of causes in two main categories of sources of change: internal and external (Almasi et al., 2011; Charkhakan & Heravi, 2012; Hui et al., 2017; Peter ED Love, 2002; Rashid Maqbool & Yahya Rashid, 2017; Ming Sun et al., 2006; Ming Sun & Meng, 2009; M Sun et al., 2004). External causes are associated to technological changes, changes in customers' expectations, changes in activities of competitors, changes in policies from government, and changes on economic conditions (Ming Sun et al., 2006). Internal causes result from changes in management of companies, organizational objectives, and changes on strategies from the organizations involved (Ming Sun et al., 2006).

Moreover, Ming Sun and Meng (2009) generated a comprehensive overview on project change causes and developed a taxonomy in this regard. The research develops in five categories, being: project-related, client-related, design-related, contractor-related, and external factors (Ming Sun & Meng, 2009). Likewise, Bröchner and Badenfelt (2011) recognized the main reasons of change in IT projects in three categories: client-related, supplier-related and external-related changes (Almasi et al., 2011). Similarly, Mohamad, Nekooie, Al-Harthy, and Amur (2012) and Keane et al. (2010) categorized the sources of design changes in clients or owner related, consultant-related and contractor related, being these the principal parties in construction projects. As well, one more category was added for those causes which were not related with the main parties of the projects: “other variations” (Keane et al., 2010). As it can be seen clients, consultants and contractors are considered critical parties in construction projects, that is why many times design changes that have an impact on the project occur because to intentional, unintentional or negligence from one of these players (Aslam et al., 2019). This is the reason why these appear as categories of changes in projects by many authors. Furthermore, Hsieh et al. (2004) distinguish two main categories of change causes: technical and administrative. They highlight four types of technical causes: planning and designs, underground conditions, safety considerations and natural incidents. On the other hand, the administrative changes can be: changes in work regulations, changes of decision-making authority, special needs for project commissioning and ownership transfer, and neighbourhood pleading (Hsieh et al., 2004).

Causes of changes in construction projects are usually produced from design or construction activities (Atkinson, 1999; Peter ED Love & Li, 2000; Ming Sun et al., 2006). Design generated causes include design errors and omissions, which are one of the main causes for change in construction phase, and can be due to human error, poor brief development, wrong assumptions and understanding of requirements (Hsieh et al., 2004; Ming Sun & Meng, 2009) and lack of effective communication among parties (Lehmann, 2010). Contrastingly, owners requirements can change, and often do, creating the need to modify design solutions (Ming Sun & Meng, 2009). Additionally, Rashid Maqbool and Yahya Rashid (2017) and Hsieh et al. (2004) argue that design changes can be due to defects and inconsistencies in designs, insufficient detail in drawings, obstacles in preparing design materials and inappropriate specification.

Factors	Causes of design changes	Source
Client-related	Change requirement/specification	Chang et al. (2011), Hui et al. (2017), Hsieh et al. (2004)
	Frequent scope change by the client	Aslam et al. (2019), Hansen et al. (2020)
	New technology	Sun et al. (2004), Hui et al. (2017)
	Omission of scope	Hui et al. (2017), Alnuaimi et al. (2010), Memon et al. (2014)
	Inappropriate choice of contract type	Maqbool & Rashid (2017), Aslam et al. (2019)
	Unclear brief	Hui et al. (2017), Brochner & Badenfelt (2011)
	Value engineering (cost savings, alternative materials)	Hui et al. (2017), Khalifa & Mahamid (2019)
Design-related	Time constraints	Chang et al. (2011), Aslam et al. (2019), Hansen et al. (2020)
	Modification to design	Hui et al. (2017), Alnuaimi et al. (2010)
	Design errors	Maqbool & Rashid (2017), Hui et al. (2017)
	Design omissions	Chang et al. (2011), Hui et al. (2017)
	Outdated design (new technology)	Wu et al. (2004), Hui et al. (2017)
	Inadequate information provided to designer	Aslam et al. (2019), Alnuaimi et al. (2010)
	Designer noninvolvement during construction phase	Aslam et al. (2019)
	Discrepancies between contract documents	Aslam et al. (2019), Hsieh et al. (2004)
	Lack of awareness of governmental regulations/municipality requirements	Aslam et al. (2019), Hsieh et al. (2004)
	Incomplete drawings	Padala et al. (2020), Memon et al. (2014)
Contractor-related	Request to use available materials	Hui et al. (2017), Wu et al. (2005)
	Alternative construction methods	Hui et al. (2017), Wu et al. (2004), Sun et al. (2009)
	Incomplete plans and specifications	Aslam et al. (2019), Hsieh et al. (2004)
	Request/suggestion on improving buildability	Aslam et al. (2019)
	Insufficient working drawing details	Aslam et al. (2019), Wu et al. (2005)

Figure 7 - Causes for design changes

Process-related	Poor project organizational structure	Maqbool & Rashid (2017), Aslam et al. (2019)
	Unpredictable circumstances during construction	Hui et al. (2017), Almasi et al. (2011)
	Lack of coordination and communication	Padala et al. (2020), Khalifa & Mahamid (2019)
	Information problems	Aslam et al. (2019), Brochner & Badenfelt (2011)
	Fragmented schedules	Padala et al. (2020), Alnuaimi et al. (2010)
	Overlapping of design and construction phase	Padala et al. (2020)
Site-related	Underground conditions	Wu et al. (2004), Hui et al. (2017), Hansen et al. (2020)
	Site layout and access	Padala et al. (2020), Hsieh et al. (2004)
	Differing site conditions	Sun et al. (2004), Aslam et al. (2019), Wu et al. (2004)
External-related	Economic conditions	Hui et al. (2017), Charkhakan & Heravi (2012)
	Government policy/issues	Wu et al. (2004), Chang et al. (2011), Hui et al. (2017)
	Problems with neighbors	Hui et al. (2017), Almasi et al. (2011), Hsieh et al. (2004)
	Severe weather	Sun et al. (2004), Aslam et al. (2019), Wu et al. (2004)
	Unexpected changes in material availability	Aslam et al. (2019), Khalifa & Mahamid (2019)

Figure 8 – (Continuation) Causes for design changes

For this research the causes for design changes will be established based on the extensive work of researchers that have focused in design changes specifically and their causes, such as: Aslam et al. (2019), Hui et al. (2017) and Padala et al. (2020). However, these researchers have divided their research into different categorization of factors causing changes. As a result, in this study a new classification of design change causes is carried out based on these scholars and their research, in the search of an exhaustive categorization. The new categorization be seen in Figure 7 and 8. The table is done by complementing the findings of the different scholars, and comparing their findings, with the aim of generating a thorough framework for this research thesis. The categories included in the table are Client-related, Design-related, Contractor-related, Process-related, Site-related, and External-related. Within these categories several causes were found. For a better understanding of the impact that these changes might have, a full-scale exploration of design change effects is carried out in the next section.

2.9 Effects of Design Changes

Changes in projects may have different kinds of impacts. Impact of a change defined by Almasi et al. (2011) is “any positive or negative net consequences it has on project’s components, especially on its budget and schedule” (Almasi et al., 2011). Different scholars have researched the impacts of changes in projects and created different categories based on their findings. Keane et al. (2010) established five categories for change effects based on the literature survey findings: cost, quality, time, organization-related effects, and other effects. Similarly, Padala et al. (2020) defined three main categories

related to: time, cost, and others. Moreover, Memon et al. (2014) found nine effects of changes overall, these are: delay in completion, increase in project cost, quality of projects affected adversely, causes rework, logistics delay, loss of productivity, causes non value adding activities, unnecessary procurement, and slower project progress.

Conversely, in the research by Hui et al. (2017) it is stated that changes will inevitably degrade the project performance, due to rework. Rework has been indicated by several authors to be the cause of disruptions and delays in construction projects, as a consequence of changes (Hui et al., 2017). Ming Sun and Meng (2009) also claim that indirect effects of project changes will damage performance of projects. Delays will also be a consequence due to loss of productivity in projects (Hanna et al., 2002), morale and coordination issues (Hui et al., 2017). In the research by William Ibbs, Long D Nguyen, and Seulkee Lee (2007b) it is claimed that disruptions caused by changes can be foreseeable or unforeseeable.

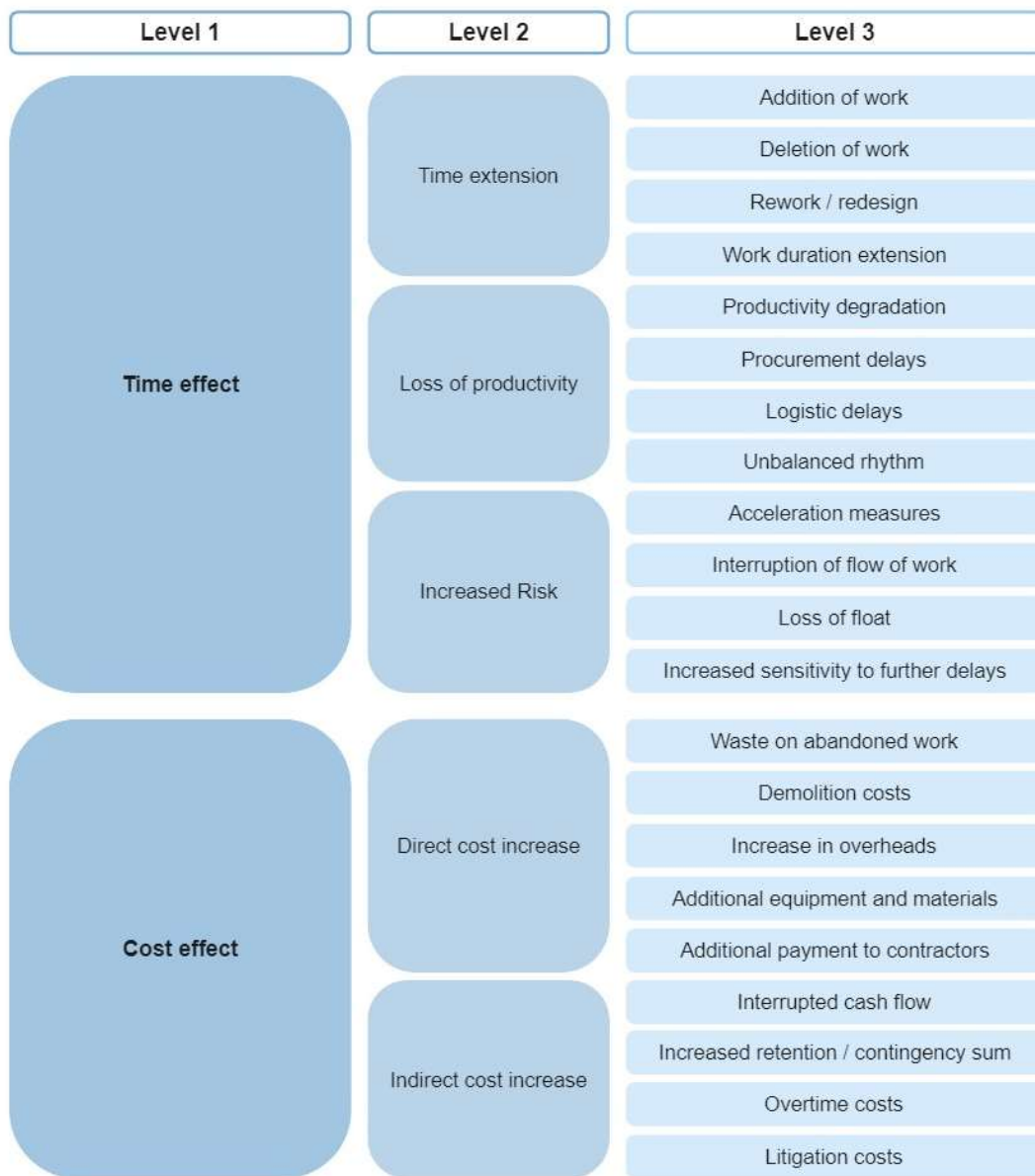


Figure 9 - Taxonomy of change effects adapted from Ming Sun and Meng (2009)



Figure 10 - (Continuation) Taxonomy of change effects adapted from Ming Sun and Meng (2009)

Foreseeable may occur in same time, place or resource as changed work, while unforeseeable can occur at a time, place or resources different from the changed work (Ibbs et al., 2007b).

Almasi et al. (2011) highlight that no matter which type of impact it is dealt with, the intensity of these impacts is not the same. The level of impact can be between low or high, and be dealing with one or more areas of the project such as: scope, schedule, cost, quality, and resources (Almasi et al., 2011). Motawa et al. (2007) explain that these effects may be beneficial, neutral, or detrimental. As well, impacts of changes can be direct, like disruptions and delay, or indirect, as consequential effects on other factors (Almasi et al., 2011). However, no matter if it is a direct or indirect impact on the project, both are of same significance.

To what refers to this research, the classification of design change effects will be based in the taxonomy created by Ming Sun and Meng (2009). As found in the exhaustive literature study, the types of effects that are constantly mentioned by scholars tend to be similar and repetitive. These categories of effects are mainly: impacts on time, impacts on cost, and impacts on people. The categories for this “taxonomy” are divided in three “levels”, being “Level 1” the general category, “Level 2” a more specific aspect of the effect, and “Level 3” a very specific description of the effect of changes in projects. Within these three categories, several specific effects were encountered, however it is observed how many specific effects have the same overall impact on projects, “Level 1” effects. This can be observed in Figure 9 and 10.

2.10 Insights of Current Practice

Following the in-depth literature review, it was clear the highly academic perspective of the information gathered and the need of diminishing the scope of this thesis. In order to have a more comprehensive understanding on the subject, the in-depth literature study was complemented with some explorative interviews. These interviews were carried out with practitioners who daily deal with project planning and scheduling with the aim of adding insights from the practice to the available literature, in an attempt to understand the different perspectives on the matter. As explained by Onwuegbuzie, Leech, and Collins (2012) the use of multi-source research grants the possibility of combining information, in order to get a greater understanding on the issue at hand and enhance the reliability of the analysed data. Consequently, from the insights of practice, information of the current needs will be gathered, and used as an aid for reducing the scope of this research while adding value to it.

OVERVIEW OF INTERVIEWS

The interviews were performed within the company where this graduation thesis is being carried, DPR Construction. The interviews performed were semi-structured and of an explorative nature. The decision to carry semi-structured interviews was based on Alshenqeeti (2014) argument on the flexible quality of this type of interview, which makes easier the possibility to expand the responses of the interviewees by the addition of following questions in the course of the interview. Furthermore, the explorative aspect is grounded intrinsically into the definition of the word, which Swedberg (2020) describes as the attempt to discover something by introducing oneself into the subject field, being this the purpose of these interviews as a way of gaining insight into the current practice. In total three interviews were performed with a duration of an hour.

	Interviewee 1	Interviewee 2	Interviewee 3
Role in the company	Regional Planner within the DACH area	Planning Manager of a specific project in Switzerland	Planning Manager in a project in DACH region
Experience	24 years of experience in the industry	5 years of experience in planning construction projects	7 years of experience in the industry
Responsibilities of role in DPR	Is part of every project within this region, assists planning managers of each project and acts as a supervisor and link with clients	As a planner oversees the plan and schedule of the project, its creation, control and adaptations needed.	Supervises the project schedule and plan, being in charge of any changes in the schedule and maintenance of the plan.

Figure 11 - Practitioners from for Explorative Interviews

All interviewees work within the planning team in the DACH region, having different roles in the projects and DPR's organization, with the intention to have a more heterogeneous pool of practitioners specialized in the planning aspect. DACH is an acronym for the region conformed by the German speaking countries of Germany (D), Austria (A) and Switzerland (CH).

The interview consisted of four parts: an introduction, general questions, questions about changes in projects and flexible management approach questions. The introduction served as a way for practitioners to fully understand the scope of the research and the aim of this interview. The general questions part starts with gathering personal information from practitioners and their work experience, following by questions about processes within DPR Construction projects in a generalized manner. Furthermore, the questions about changes in projects were focused on the experience of the practitioners in projects and their insight into timing, frequency, causality and impacts of changes. While the questions of flexible approaches tried to understand the mindset and knowledge about flexibility in practice, in order to understand its status and possible use. For more information about the structure of the interview see Appendix D.

The analysis of the data gathered in the interviews was of a qualitative nature. After gathering the information from the interviews and creating the transcriptions of each interview, this was analysed by means of a content analysis of the information and later contrasted between the different interviewees to reach to conclusions. In the following section the analysis is presented.

ANALYSIS OF DATA GATHERED

After the execution of the literature study, the need to understand practitioners' perspectives and experiences was deemed as crucial. In this section it will be analysed first the aspect of changes and the insights from the interviewees, and secondly the aspect of flexibility.

Changes in projects

Changes are described as being a common aspect of projects and have a high frequency of appearing in projects, even though there were differences between the interviewees, there was a consensus that changes appear weekly in most projects and can appear as frequently as daily in others. Changes are processed differently depending on whom is the change coming from. But overall, the changes are assessed in terms of impact (time and cost) and communicated to the parties involved in the change being not only within the organization of the company but to the client and subcontractors, or trades, in charge of it. The assessment of changes generally is done with the help of the expertise of the different trades, since the "waterfall effect" can create secondary changes. Communication of changes are done in weekly meetings on site, as well as using an internal platform of the company. After everyone is informed a decision must be taken, normally this is a negotiation between parties until a decision is reached, following the change is implemented. An aspect to call attention to is the fact that not always changes are formalized, meaning that not always a change/variation

order is created. This tends to happen when the changes do not have impacts in aspects such as cost, time, or quality. If changes are not formalized is the contractor, or one of the subcontracts, the one that is absorbing the change.

Types, causes and effects of changes recognized in practice

The changes recognized by practitioners are mainly two types of changes: scope changes and design changes. Changes in scope are mentioned as a consequence of clients signing a tenant or end user for the project, having to adapt different aspects depending on the requirement of the tenant. However, design changes are mentioned to have the following causes:

- Caused by lack of information available in the first phases of the project.
- Caused by poor project design or definition.
- The specifications of equipment to be installed provokes changes.
- Changes caused by lack of quality.
- Undisclosed information to design team by the client or consultant.
- Caused by different requirements or legislation from country to country creating changes.

Even though practitioners recognize changes can appear in every phase of the project, they are in unison with the fact that changes mostly appear in the execution phase. Design changes are emphasized as being very disruptive in projects, since design changes normally have secondary effects on different trades, generating more changes. The impact of these changes in the project tends to be in factors as cost, time, and quality. However, impacts of changes are not conclusive since some changes can lead to no impacts on these factors. The effects of changes in planning and scheduling mentioned by practitioners can be observed in Appendix E. These effects can be summarized as:

- Delays.
- Extension of initial schedule.
- Consumption of the sequencing of tasks in the schedule.
- Substantial amount of workload inflicted on the project team, for the assessment, evaluation, and adaptation of schedule due to changes.

Strategies for managing changes in projects

The interviewees brought up various strategies they use to solve, or diminish, the effects of the changes that arise within projects. These strategies can be separated in two categories: reactive and proactive. As reactive strategies it was mentioned:

- Using up float of tasks within the schedule.
- Re-sequencing using Lean techniques.
- Addition of labour.
- Analysis of timing to implement the change in the schedule (out of critical path).
- Agility when reacting to changes.

- Meetings with parties involved in project to reach a common strategy to tackle changes in the least disruptive way.

Moreover, as proactive strategies they brought up the following:

- Improve coordination and collaboration between parties.
- Create mitigation plans.

Interviewee 1 highlighted during the conversation the fact that how changes are processed within the company varies between projects depending on the characteristics of its procurement. As a matter of fact, the procurement of the project can affect the way changes are seen by, not only the contractor but every party involved. Traditional contracts, where project design is a responsibility of the client, will make changes be considered variations of the contract. Even though changes are negotiated with the client, if changes have impacts these will be part of the responsibility of the client. While in a contract like Design Bid Build, changes that arise in the project are not so simple to solve not find the responsible party. Especially being a construction company, DPR Construction absorbs changes that not always are responsibility of the company but are used as a business negotiation technique.

Flexibility in Project Management

About the last part of this interview, flexibility in project management was not as straightforward for the practitioners interviewed. The concept of flexibility within project management was not clear to define, and the interviewees mentioned aspects as “be able to move with the change”, “unison”, “quickly”, and “making it easier”. Interviewees claimed to not have knowledge on practices or tools that add flexibility into project management, nor they recognized to have used it in practice in any way. Furthermore, when asked about which benefits, they found in the use of flexibility in planning, interviewee 3 answered to have an increase in coordination between the different parties, while interviewee 2 agrees that flexible tools may help with coordination and communication between parties in the project. Nevertheless, the drawbacks of the use of flexibility were accentuated by the different interviewees. Interviewee 1 mentioned how often it happens in projects that not everyone is trained or resourced for specific ways of working. This can be within the company itself or in relation to trade partners, making it almost impossible to implement practices or tools. Interviewee 3 could not find any drawback on what he understands as flexibility. And interviewee 2 agrees partially with interviewee 1 when saying that sometimes some tools are too difficult for everyone to understand it and use it correctly, which could lead to increased drawbacks for the number of benefits gained.

Lastly, interviewee 2 seem reluctant to the possibility of flexible tools be able to help with changes in projects and attested for the fear of losing control of the project or “things to fall through the cracks”. While Interviewee 1 was not able to tell since has never used this. And interviewee 3 considers that if there is more communication and collaboration as a result of flexibility, this will bring more knowledge about the changes in projects making easier taking decisions and understand the possible impacts on schedule and planning.

DEDUCTIONS

In short, the type of change that causes greater distortion in projects tend to be design change. The causes of this type of change indicated by practitioners were the following:

- Caused by lack of information available in the first phases of the project.
- Caused by poor project design or definition.
- The specifications of equipment to be installed provokes changes.
- Changes caused by lack of quality.
- Undisclosed information to design team by the client or consultant.
- Caused by different requirements or legislation from country to country creating changes.

Besides, it was observed that the strategies to manage changes can be proactive or reactive. Interviewees stress the importance of proactive actions, such as collaboration and coordination between parties, to be able to manage the impact and effects of changes in projects.

Additionally, interviewees seem to understand benefits and drawbacks from the use of flexibility, but still do not recognize what flexibility is nor practices that add flexibility in the planning, which is contradictory. It was evinced an unconscious use of these practices in their daily activities.

Finally, it should be mentioned that when carrying out the interviews it was astonishing to see the different opinions and experiences on change practitioners have, and how this depends on the projects they have worked on and their characteristics.

2.11 Conclusion

As discussed throughout this chapter the concept of flexibility is complex and broad, being an ongoing research topic by scholars and its applicability. Different definitions of flexibility have been discussed and highlighted the one to be used for this research. The concept of flexibility in planning and scheduling has been widely discussed and possible strategies for implementing it into practice have been determined as flexibility recourses. When comparing the data gathered from the practitioners' interviews and the one coming from the extensive literature review, it is needed to mention that despite the differences in the terms used, these flexibility recourses are being used in practice for managing projects, even without acknowledging them as such.

Furthermore, the concept of changes in projects, its types, causes, and effects were discussed thoroughly. The exploratory interviews reflected much of what was established in the extensive literature study with what regards to changes. As named in literature the most frequent type of changes is due to the design of the project or its scope. The

emphasis of the interviewees was on design changes, due to the substantial disruption they cause within the project and the frequency with which they arise in projects. Thus, the scope of the research will be focused on this type of change, reducing the reach of this research. As well, the causes of change indicated by practitioners was fairly similar to the causes indicated in the literature, and the ones which were not are added to the research complementing it with perspectives from practice, see Figure 12.

Overall, this chapter has reviewed the concept of flexibility in project management, and in terms of planning and scheduling. Additionally, a framework of eight recourses for flexibility in planning has been built from several literary sources and a categorization of design change causes in construction projects has been put together with the aid of practitioners' insights. Throughout this chapter, not only answers to the first two sub-research questions have been answered, but the flexibility recourses in planning and the design change causes which will be the base for the following steps of the research has been established.

Factors	Causes of design changes	Source
Client-related	Change requirement/specification	Chang et al. (2011), Hui et al. (2017), Hsieh et al. (2004)
	Frequent scope change by the client	Interviews, Aslam et al. (2019), Hansen et al. (2020)
	New technology	Sun et al. (2004), Hui et al. (2017)
	Omission of scope	Hui et al. (2017), Alnuaimi et al. (2010), Memon et al. (2014)
	Inappropriate choice of contract type	Maqbool & Rashid (2017), Aslam et al. (2019)
	Unclear brief	Hui et al. (2017), Brochner & Badenfelt (2011)
	Value engineering (cost savings, alternative materials)	Hui et al. (2017), Khalifa & Mahamid (2019)
Design-related	Time constraints	Chang et al. (2011), Aslam et al. (2019), Hansen et al. (2020)
	Modification to design	Hui et al. (2017), Alnuaimi et al. (2010)
	Design errors	Maqbool & Rashid (2017), Hui et al. (2017)
	Design omissions	Chang et al. (2011), Hui et al. (2017)
	Outdated design (new technology)	Wu et al. (2004), Hui et al. (2017)
	Inadequate information provided to designer	Interviews, Aslam et al. (2019), Alnuaimi et al. (2010)
	Designer noninvolvement during construction phase	Aslam et al. (2019)
	Discrepancies between contract documents	Aslam et al. (2019), Hsieh et al. (2004)
	Lack of awareness of governmental regulations/municipality requirements	Interviews, Aslam et al. (2019), Hsieh et al. (2004)
	Incomplete drawings	Interviews, Padala et al. (2020), Memon et al. (2014)
Contractor-related	Request to use available materials	Hui et al. (2017), Wu et al. (2005)
	Alternative construction methods	Hui et al. (2017), Wu et al. (2004), Sun et al. (2009)
	Incomplete plans and specifications	Interviews, Aslam et al. (2019), Hsieh et al. (2004)
	Request/suggestion on improving buildability	Interviews, Aslam et al. (2019)
	Insufficient working drawing details	Interviews, Aslam et al. (2019), Wu et al. (2005)
Process-related	Poor project organizational structure	Maqbool & Rashid (2017), Aslam et al. (2019)
	Unpredictable circumstances during construction	Hui et al. (2017), Almasi et al. (2011)
	Lack of coordination and communication	Padala et al. (2020), Khalifa & Mahamid (2019)
	Information problems	Interviews, Aslam et al. (2019), Brochner & Badenfelt (2011)
	Fragmented schedules	Padala et al. (2020), Alnuaimi et al. (2010)
	Overlapping of design and construction phase	Interviews, Padala et al. (2020)
	Insufficient working drawing details	Aslam et al. (2019), Hansen et al. (2020)
Site-related	Underground conditions	Wu et al. (2004), Hui et al. (2017), Hansen et al. (2020)
	Site layout and access	Padala et al. (2020), Hsieh et al. (2004)
	Differing site conditions	Sun et al. (2004), Aslam et al. (2019), Wu et al. (2004)
External-related	Economic conditions	Hui et al. (2017), Charkhakan & Heravi (2012)
	Government policy/issues	Wu et al. (2004), Chang et al. (2011), Hui et al. (2017)
	Problems with neighbors	Hui et al. (2017), Almasi et al. (2011), Hsieh et al. (2004)
	Severe weather	Sun et al. (2004), Aslam et al. (2019), Wu et al. (2004)
	Unexpected changes in material availability	Aslam et al. (2019), Khalifa & Mahamid (2019)

Figure 12 - Design Change Causes with data from interviews

3. RESEARCH METHODOLOGY

In the last chapter, after carrying out an extensive literature review and exploratory interviews, the causes of design change and flexibility recourses in planning for construction projects were identified. Given the short supply of literature available on the use of flexibility in terms of planning for managing changes in construction projects, it was necessary to investigate if a relationship between these two factors exists and what type of relationship there is. By understanding the (non)existence of a relationship between these flexibility recourses in terms of planning and the causes of design change in construction projects, an assessment of its possible use for managing changes can be done. Consequently, a correlation analysis was chosen as the methodology for researching the (non)existence of a relationship between flexibility recourses and causes of design change. In this chapter the correlation analysis and the process of data gathering will be elucidated.

3.1 Correlation Analysis

Correlation analysis is a quantitative method and can be used to assess the relation between two variables. The assessment of the relation will be done by describing the strength and the direction of a linear relationship between the two variables. Within correlation analysis there are several options of which to choose to carry out the correlation. However, there are two commonly used types in social sciences: Pearson product-moment coefficient and Spearman's rho (Pallant, 2013). Even though the method used is quantitative the data analyzed is of the qualitative type. Pearson product-moment is majorly used to variables measured by intervals or ratios, while Spearman's rho is used with variables measured categorically or by ordinal scale (Pallant, 2013).

The correlation takes values from -1 to +1. The sign indicates the direction of the relationship: positive or negative. Positive relationship means that when one variable increases the other does as well. However, negative relationship means when one variable increases the other decreases. The absolute value indicates the strength of the relationship, being stronger the closer to 1 which is a perfect correlation. If the absolute value is 0 means that there is no relationship

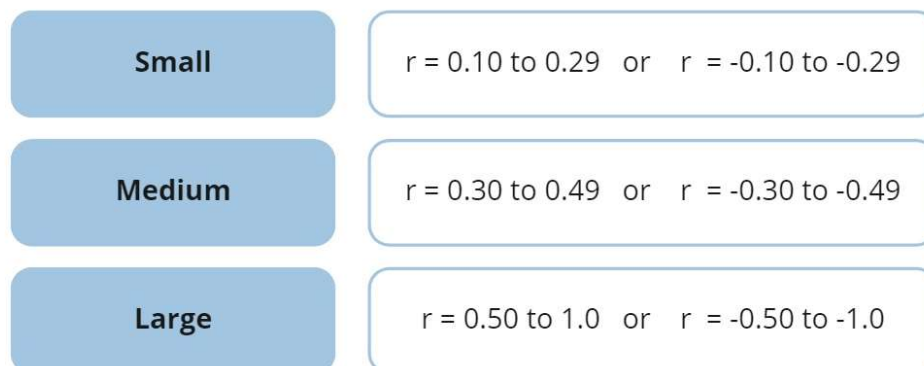


Figure 13 - Levels of relationship strength - adapted from Cohen (2013)

between variables (Pallant, 2013). The size of the correlation, the strength of the relationship between variables, is interpreted differently depending on the author. For example, Cohen (2013) suggests 3 levels of strength: small, medium and large (see Figure 13).

For this correlation analysis a double-sided approach was used because the direction of the relationship is not the focus here since what we are trying to find is the relation in itself. This can be observed in Figure 14. The hypothesis to be examined suggests the existence of a relation between Flexibility Recourses and Design Change causes. The null hypothesis in this research would be the lack or absence of a relation between the two variables.

3.2 Data Gathering

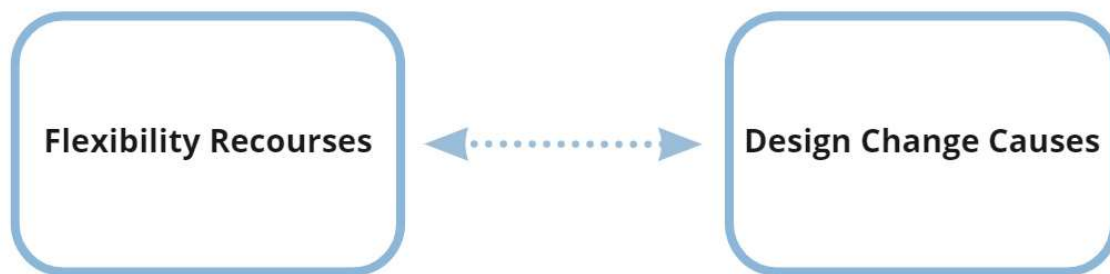


Figure 14 - Conceptual model of relationship between variables

In this section the decision-making process prior to collecting the data for the correlation analysis will be discussed. For this analysis practitioners will be asked to select a project they have worked on recently and assess the appearance of different causes for design change and flexibility recourses used in practice. For making this possible, the frameworks discussed in chapter 2 will be used as the basis for this collection of data. This section will firstly explain the strategy for the data gathering process, following the construction of the method employed for gathering the data will be discussed, and finally, the targeted practitioners as sources of the information will be presented.

DATA GATHERING APPROACH

The data gathering will be carried out by means of a questionnaire, this lets the data collected generalizable between the big number of respondents that are needed as a suitable sample for the correlation analysis. This will be emphasized by the use of close-ended questions. The questionnaire will be distributed as a web survey, the reasoning behind this decision is based on Veltri (2019) and the following factors: speed, geographical boundaries and time boundaries. The factor “speed” contemplates not only the time spent collecting the data as faster than other methods, but also the data is faster prepared for being analysed. “Geographical boundaries” contemplate the place where the respondents are, given the fact that DPR employees are dispersed through several countries within Europe this would make it easier to gather the information needed. And the “time boundaries” refers to the characteristic that respondents can answer the survey at any time of day whenever they find it convenient (Veltri, 2019). This survey will be carried out using Microsoft Forms,

since the company has access to it and has a good interface for the type of questions that will be asked. Apart from these two reasons, the tool has the option to design the survey for other devices that are not computers, such as tablets and smartphones. This has been noted as one of the pitfalls for web surveys by Veltri (2019), thus, the decision to use this tool and design an easy to use interface design (see Appendix F). For analyzing the data gathered, the correlation analysis will be carried in IBM SPSS Statistics 26. Although this program is only one of the possibilities for realizing this type of analysis, this tool is easily accessible for TU Delft students and is specific for its applicability in social sciences studies.

CONSTRUCTION OF SURVEY QUESTIONS

The survey will be set up in five sections, being: general personal questions, characterization of selected project, design change causes in projects, flexibility strategies in planning, optional questions to assess flexibility in project management. The survey was designed to last only 15 minutes to be completed, since this can negatively affect the quantity of responses that can be gathered. The longer the survey, the less responses collected. Below, every section of the survey will be discussed and the reasoning behind it explained.

Section 1: General Personal Questions

This section will provide context about the respondents to understand whether these characteristics could influence in the way the different practitioners may answer the questions. When determining the questions for this section the anonymity of the respondents was considered, making sure that the questions are not too personal to compromise this.

Section 2: Characterization of selected project

This section aim is to gather information on the selected project by the respondent. Within this second part of the survey two main sub parts can be observed. The first one refers to naming the project, the type of client, its location and expected duration and phase in which the project is on. And the second one analyzes the perceived complexity of the project by the practitioner. To be able to assess this it was used an existing framework since the creation of this framework would fall out of the scope of this research, the framework selected was the TOE framework by Bosch-Rekvelde, Jongkind, Mooi, Bakker, and Verbraeck (2011). This framework was selected due to its completeness by including several aspects from frameworks established by other scholars. By using the TOE framework and a Likert scale, an analysis on the complexity of the project can be achieved. This will help to understand the context of the projects, aiding in the analysis of the reasoning behind the responses collected by the survey. Knowing that the perceived complexity may have some influence on the changes that arise in projects and the way the project is managed.

Section 3: Design change causes in projects

In this section the causality of changes will be assessed. For it the framework established in Chapter 2 will be used. This framework consists of information gathered by exploratory interviews and several studies by different scholars

amalgamated in one final framework (see Figure 12). This framework consists in 6 categories conformed by a total of 36 causes of design change. Since the questionnaire needs to be simple and easy to complete, the questionnaire was designed as a set of 36 statements and the respondents were asked to assess these using a Likert scale. The Likert scale used was a five-point scale with a frequency range from Never to Almost Always. Having a five-point scale gives the option of having a neutral answer, although it is not useful for the correlation analysis this option must exist to not force respondents into a direction and abandoning the survey before completion. As well, two more options were added: “I do not know” and “Not applicable”. This options, even though they may seem similar, give two different perspectives for the analysis of the data gathered.

The different causes of design change have been transformed into simple statements. The simplicity of the statement and the language used was carefully thought and designed to make the survey easy to fill in and interpret by the practitioners. Before releasing the survey, it was tested on 3 different practitioners with different backgrounds and nationalities to make sure that the English used would be understandable for different terms around the globe. Another aspect that should be mentioned is that statements were design to be interpreted as positive on design change causes, this means that they are directed towards higher design changes. This was designed to be easier for the respondents to follow the statements, and to simplify the analysis and diminish the possibilities for errors.

Section 4: Flexibility strategies in planning

To assess the implicit use of flexibility recourses in practice the framework created in Chapter 2 was used as a base. In that framework different elements for increasing flexibility in the planning of projects found in literature were analyzed. From that analysis a categorization of elements was created, and 8 flexibility recourses were established (see Figure 5). In order to practitioners assess the flexibility recourses in the survey the concepts of these recourses were translated into statements. Some of the recourses needed several statements to be able to include the whole concept behind it. In Figure 15 the different flexibility recourses and their corresponding survey statements are presented. The flexibility recourses are based in several existing literature and methodologies, since mentioning any kind of names would compromise the objectivity of the data none of them will be named explicitly. This could be the case of Agile and Lean, since these words come with a previous judgement it is better to not name them in any way to avoid bias. This is the reasoning behind not using the flexibility recourses names in the survey either since it can influence the outcome of the survey. For this part of the survey, a five-point Likert scale was also used with a frequency rate from “Never” to “Almost Always”, to keep the survey simple and fast to complete it. The interpretation of statements is equal for every statement and the same as in the third section.

Part 4

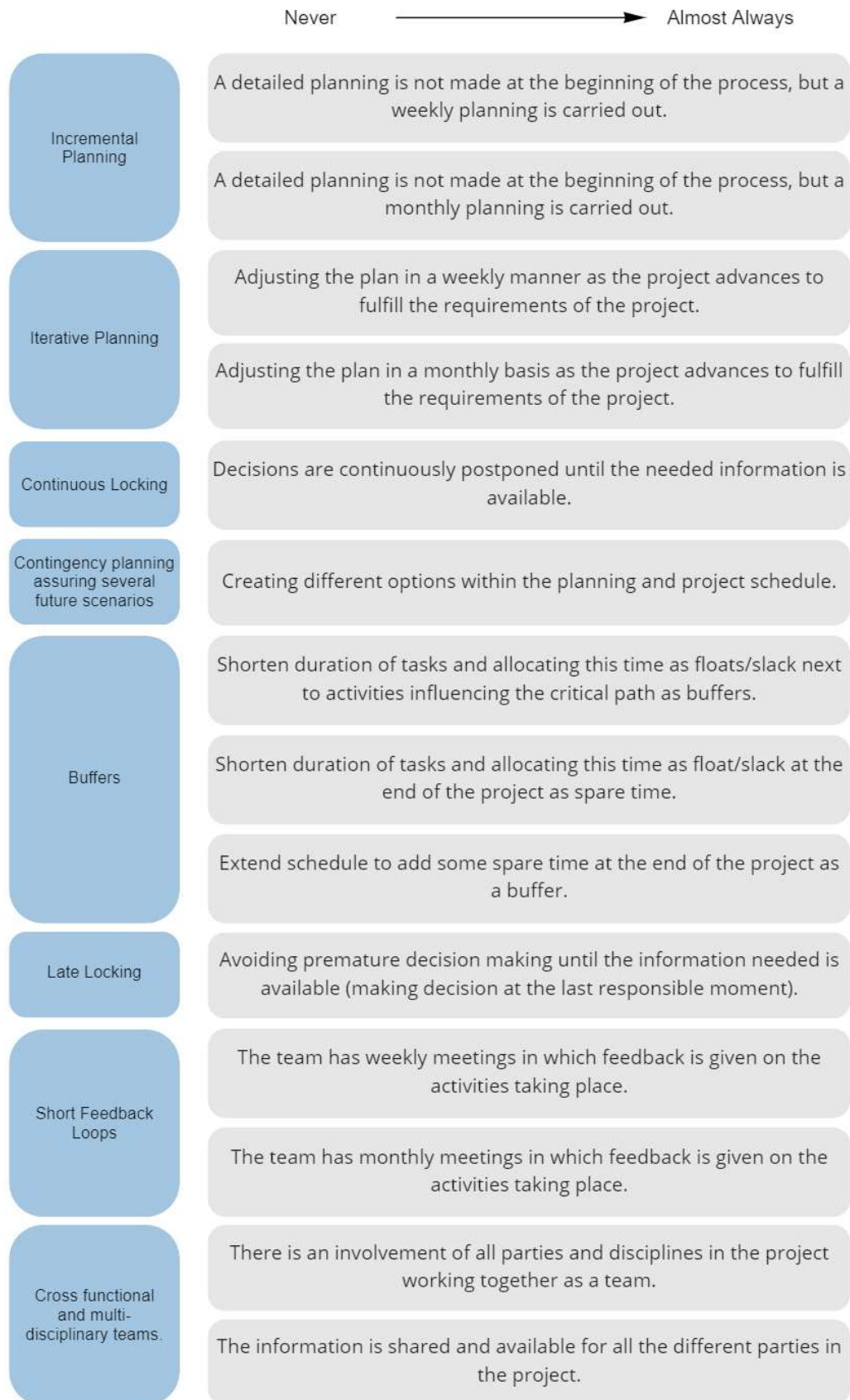


Figure 15 - Survey statements on Flexibility Recourses

Section 5: Flexibility in Project Management (optional)

For the last section of the survey a set of 5 open questions are presented, although this section is optional for the respondents that are willing to fill them in. This part was decided to make it optional since the length of the survey should not be too long, due to the possibility of affecting the response rate. As well, this section is not strictly created for the analysis of the two variables explained in section 3 and 4. The aim of this part is to collect the perspective of practitioners in DPR about flexibility in project management. This knowledge can help us understand the way these practitioners work, and which are the thoughts and opinions about flexibility. This information will be relevant when analyzing the data since it can give a sense of negativity or positivity towards the concept of flexibility. In Appendix F the 5 open questions are exhibited, these questions were based on the questions already presented for the exploratory interviews in Chapter 2.

3.3 Respondents of Survey

The survey will be carried out within DPR Construction, as the scope is limited to it. Given the great number of responses needed to carry the quantitative analysis intended for this data, not only practitioners from the European projects will be contacted but practitioners from United States as well. The respondents are selected based on their role/position in the company, since the survey is focused in one specific selected project by the respondent. The practitioners need to have knowledge on how the management in the project is done and which changes have arisen during the project. The main areas which will be contacted to fill in the survey will be Planning Managers, Project Managers, Superintendents and Project Engineers. These different roles will be explained further below.

Planning Manager: The Scheduler provides support and guidance during Proposal, Pre-Construction, Construction, and Close-Out phases of the Project with full involvement in the creation of project execution plans, milestone alignment process, proposal schedules, bid (buy-out) schedules, master schedules, production (short interval planning) schedules, and close-out schedules.

Project Manager: manages DPR commercial projects working closely with all members of the project team, responsible for the day-to-day execution, project controls, project engineering, cost, risk, and commercial and business management. Has detailed/hands-on knowledge of project scope and cost control/billings/collections and be ultimately accountable for project completion and financials, critical success factors and customer satisfaction results.

Superintendents: responsible for overseeing the day-to-day operations of a construction project from planning to completion. They create work schedules and coordinate all construction activities and contractors and conduct quality control towards on construction sites.

Project Engineer: Proactive and diligent day to day link between project management, site engineering disciplines and trade partners on projects to ensure project deliverables are met in line.

The survey was sent to 191 possible respondents within this selection via email. Respondents were contacted directly through Microsoft Teams as a reminder in two different occasions after the general email was sent. The survey had 130 responses, making the response rate barely above 68%. From those responses only 115 complied with the necessary requirements. These requirements consisted in having completed the questionnaire with less than 25% of answers being “I do not know” or “not applicable”.

In Figure 16, different data collected in the surveys about the respondents is shown. These give us an overall understanding of their expertise, level of education and current role in the company.

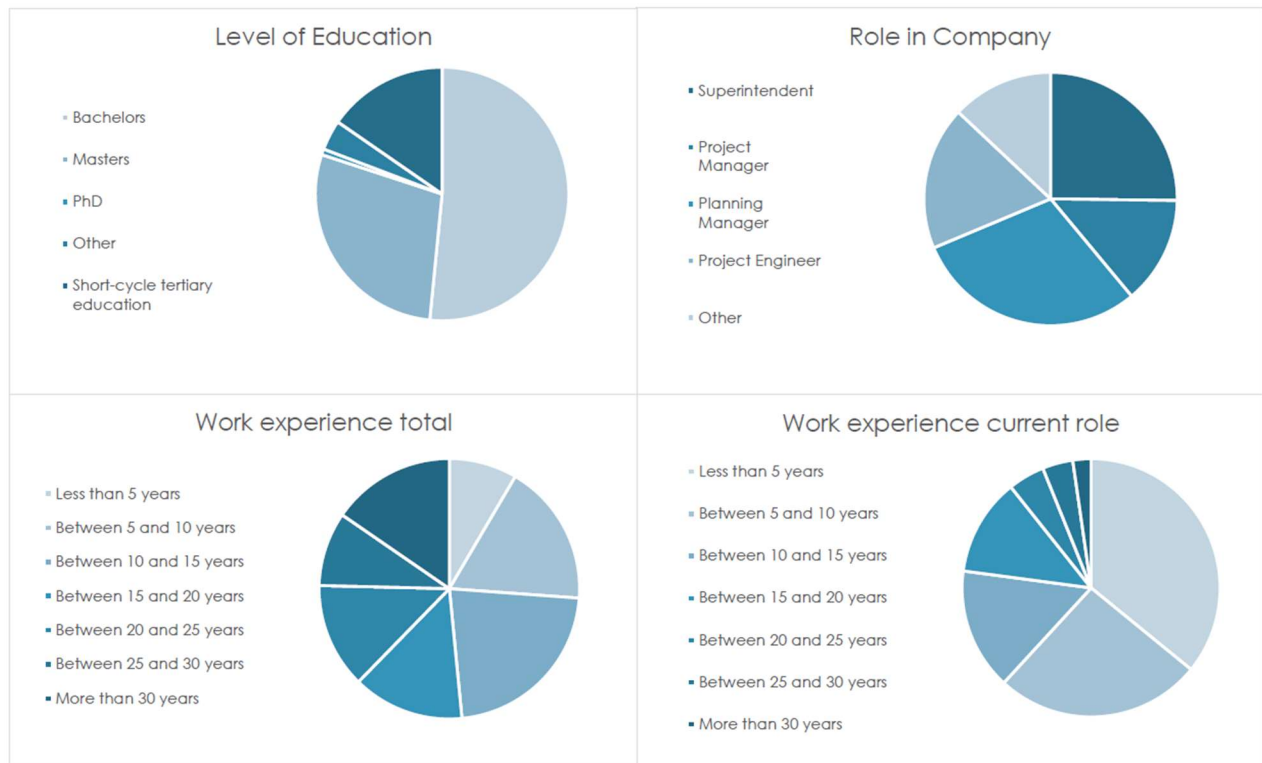


Figure 16 - Characteristics of Survey Respondents

3.4 Selected Projects for Survey

In the second section of the survey, the aim was to explore different aspects of the selected projects, not only at a characteristics level, but as well in how practitioners perceived the projects.

As can be seen in Figure 17, the majority of the respondents work in the DACH region within Europe (Germany, Austria, and Switzerland) and the projects selected are mainly in the construction phase. The proportion of respondents was a 70% from USA branch of the company, a 38% was European, and 2% from the Asian branch of DPR Construction. Mainly the projects selected by practitioners was private and the duration of the projects was predominantly between 1 and 2 years long.

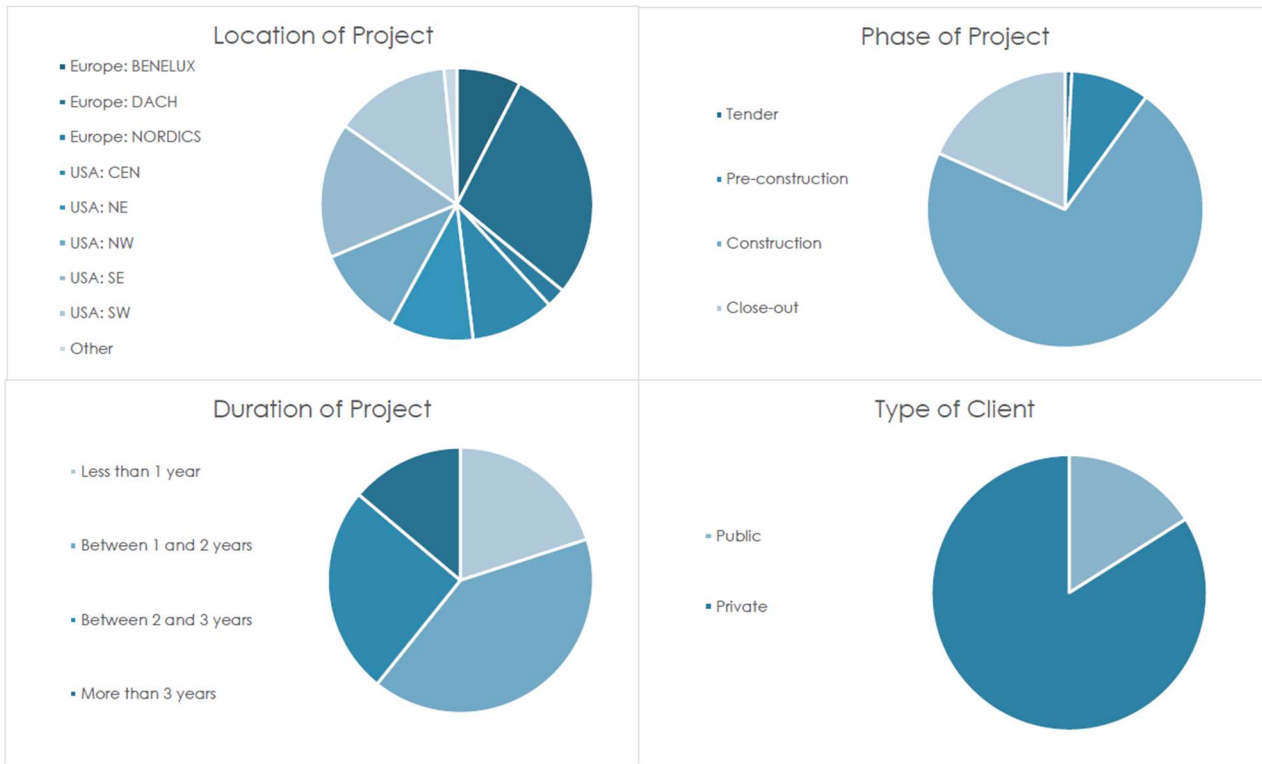


Figure 17 - Characteristics of the Selected Projects for Survey

4. DATA ANALYSIS

In this chapter the data gathered from the surveys will be analyzed. Starting with the perceived complexity by the respondents on the selected projects, following with the correlation analysis of the two sets of variables: Flexibility Recourses and Design Change Causes. Ending with an analysis on the open questions about flexibility to practitioners. This will aid in the formation of conclusions out of this analysis.

4.1 Perceived Complexity of Selected Projects

As well this section had some statements about complexity in projects based in the TOE framework by Bosch-Rekvelde et al. (2011). This framework consists in Technological, Organizational and Environmental factors for assessing and understanding a project's complexity. In this survey a total of five factors were selected from the different areas to explore how the respondents perceived their selected projects in terms of complexity. Firstly, a basic understanding of the different complexity statements will be done based on Likert scale and the percentage of responses. Secondly, a correlation analysis will be done between statements of complexity and categories of design change causes.

The interpretation of the statements, in terms of high or low complexity, varies between statements. In Figure 18 the interpretation of each is explained. When analysing these statements, the interpretation must be considered. This will be

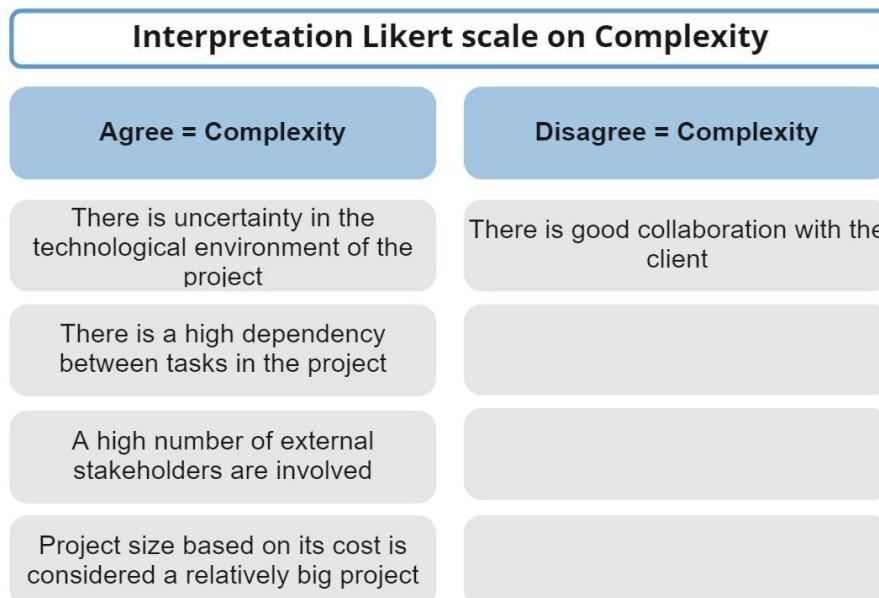


Figure 18 - Interpretation Likert Scale on Complexity

of great importance for the correlation analysis, since the data on statement “There is good collaboration with the client” will be mirrored becoming a negative statement as well, to facilitate the way reading and interpreting the relationships between variables. The results of the first analysis statements can be observed in Figure 19, following a brief analysis of the data gathered on perceived complexity by the respondents will be done.

In Figure 19, it can be observed the five statements of complexity which were presented in the survey. As a way of having a better understanding of the projects the perspective on complexity for these projects was evaluated.

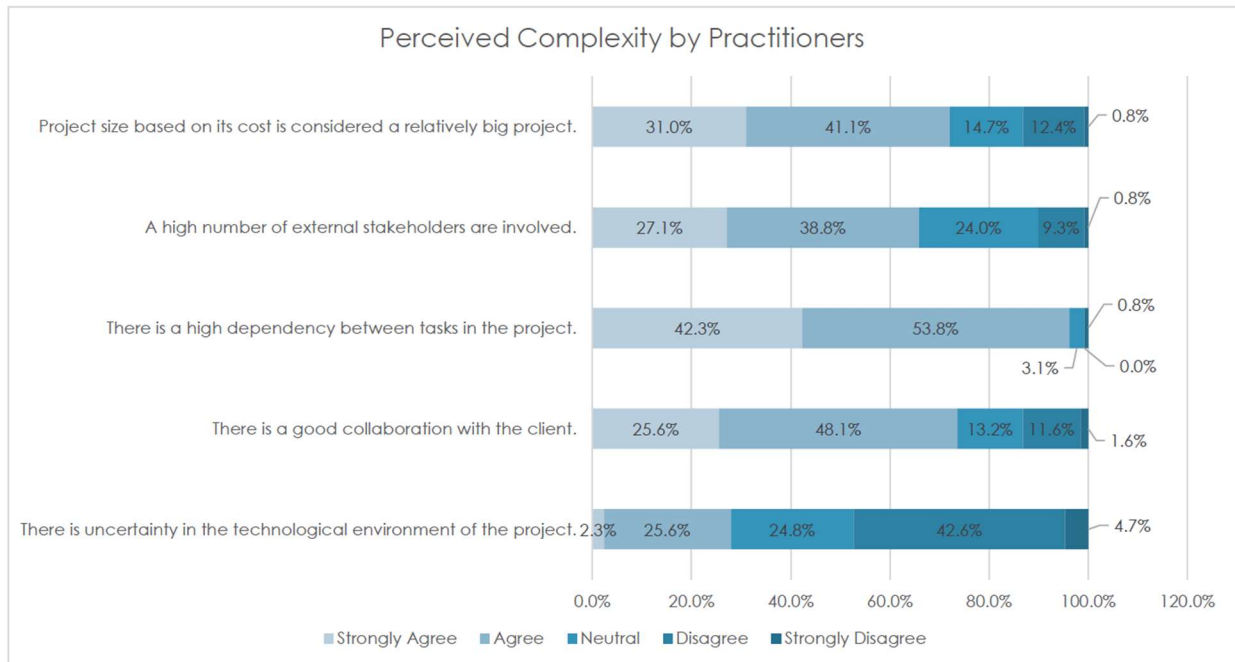


Figure 19 - Complexity Perception

The project size is predominantly big to the perception of the practitioners which is an indicator of high complexity. The same applies for the quantity of stakeholders that are part of the project, these gives an idea of the complexity that brings having so many actors within the project, which can cause fragmentation of information, slower process of communications, within others. The third statement refers to the level of dependency between the tasks, the responses were substantially in the high complexity zone, with more than 95 percent of the respondents agreeing between strongly agree and agree. This makes an emphasis on how communications are treated, as well as how the different project tasks dependency can affect in a great matter the planning of the project. Being able to have significant impacts as may be delays, rework, within others. However, the fourth statement, the collaboration with the client, seems to be lower complexity there by having good relations with the client. This may differ from the client-related causes of change to be analysed in further sections, since good collaboration does not affect the possibility of changes arising in a project. The fifth and last statement refers to uncertainty in the technological aspects of the project. Here a major part of the respondents does not find the technological aspect having high complexity, but a small portion of the respondents still believe there is a high complexity in this area.

After analysing this by percentages of answers, it was decided to do a deeper research on this topic. For this, a correlation analysis will be carried out between the complexity statements and the design change causes. It is assumed that design

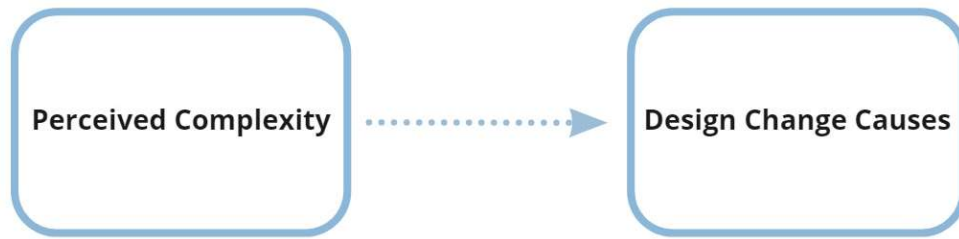


Figure 20 – Conceptual model of relationship between variables

change causes are the one set of variables that will be influenced by the complexity perceived in projects. The hypothesis to be examined suggests the existence of a relation between Design Change causes and Complexity, where complexity is the independent variable and Design Change causes the dependent one. The null hypothesis in this research would be the lack or absence of a relation between the two variables. In Figure 20 it can be observed the assumption to be studied.

After carrying out the correlation analysis between these two sets of variables, it was found that there were three significant relations between these. As it can be observed in Table 1, Design-related causes have a relationship with a

		Complexity Statement					
		There is uncertainty in the technological environment of the project	There is not a good collaboration with the client	There is a high dependency between tasks in the project	A high number of external stakeholders are involved	Project size based on its cost is considered a relatively big project	
Categories of Design Change Causes	Client-related Design Change Causes	Pearson Correlation	-0.042	0.008	0.108	0.023	0.029
		Sig. (2-tailed)	0.719	0.946	0.352	0.843	0.801
		N	77	77	77	77	77
	Design-related Design Change Causes	Pearson Correlation	0.103	0.097	.282**	0.048	0.066
		Sig. (2-tailed)	0.348	0.375	0.009	0.664	0.549
		N	85	85	85	85	85
	Contractor-related Design Change Causes	Pearson Correlation	-0.052	0.111	0.101	-0.022	0.051
		Sig. (2-tailed)	0.609	0.273	0.320	0.830	0.616
		N	99	99	99	99	99
	Process-related Design Change Causes	Pearson Correlation	0.052	0.137	0.152	0.026	0.055
		Sig. (2-tailed)	0.593	0.157	0.114	0.789	0.573
		N	109	109	109	109	109
	Site-related Design Change Causes	Pearson Correlation	0.162	.293**	-0.064	-0.114	-0.082
		Sig. (2-tailed)	0.096	0.002	0.513	0.243	0.405
		N	106	106	106	106	106
	External-related Design Change Causes	Pearson Correlation	0.008	.289**	0.021	-0.017	0.111
		Sig. (2-tailed)	0.936	0.004	0.836	0.872	0.275
		N	98	98	98	98	98

** . Correlation is significant at the 0.01 level (2-tailed).

Table 1 - Correlation Analysis between complexity and design change causes

high dependency between tasks in the project. Likewise, site-related causes and external-related causes have a relationship with the collaboration with the client in the project.

Firstly, it can be said that the first correlation will have a positive direction based on the hypothesis, meaning that if there is an increase in this complexity factor there will be an increase on design-related design change causes. In this case, if the dependency between tasks in the project increases by one unit, the design-related change causes will increase by 0.282 unit. This could be assumed to be caused given that an increase within the dependency between tasks could actually compromise the different causes within the category of design-related change causes. Such as an increase on omissions, errors and modifications within the design, an increase on the possibilities of inadequate information on different aspects affecting the design, and incomplete drawings based on the possibility of an increased dependency between tasks. Secondly, there is a significant relation between not having good collaboration with the client and site-related design change causes. Within this category aspects like changes in the underground conditions, changes about site layout and access to it, and differing site conditions in the project. This relationship establishes that when the lack of collaboration with the client in projects increases by 1 unit, the site-related change causes will increase by 0.293. The cause behind it could be assumed that without the strong collaboration some information about the site could be missing, since it is common use that a lot of ground testing and measurements on site are responsibility of the client. Thirdly, the significance correlation between external-related change causes and not good collaboration with the client is a positive one, meaning that when the bad collaboration with client increases by 1 unit the external-related change causes will increase by 0.289 unit. Furthermore, even the direction of this relationship is established, there is no logical causality that could be thought of. Due to the lack of a connection between external-related change causes to project management aspects, no logical causality behind this relationship could be determined.

Overall, it is observed that the perceived complexity in projects by the practitioners is related to the causes of design changes. However, not every relationship's causality could be determined by carrying out only this analysis. In following sections, different analysis will be carried out to research the relationship between flexibility recourses and design change causes. Further, the analysis of the open questions within the survey will be carried out. Lastly, the main conclusions of the whole analysis chapter will be presented.

4.3 Correlation Analysis

As explained in the last chapter, the analysis of the data gathered in the survey will be done via a correlation. A correlation is a statistical measure which expresses the extent for which two variables are linearly related. This means that they change together in a same scale, the correlation. This tool is commonly used to describe simple relationships between variables. The survey was conformed mainly by statements which the respondents needed to assess using a Likert scale. This Likert scale was from “Almost Always” to “Never”. It is necessary to mention that in literature there is some debate about the measurement of a Likert scale. The two options being discussed are the Likert scale being an ordinal measuring scale or a ratio (Jamieson, 2004). When adopting an ordinal scale there is a possibility of valuable results getting lost, for this reason the decision was to use a ratio scale for this analysis. Since Pearson product-moment correlation is the one

		Incremental Planning		Iterative Planning		Continuous Locking	Contingency Planning	Buffers			Late Locking	Short Feedback Loops		Cross functional and multi-disciplinary teams	
		Flex_01	Flex_02	Flex_03	Flex_04	Flex_05	Flex_06	Flex_07	Flex_08	Flex_09	Flex_10	Flex_11	Flex_12	Flex_13	Flex_14
Client-related	Change_01	-0.079	0.009	.302**	0.128	0.138	0.182	0.089	-0.084	-0.072	0.116	0.101	-0.023	0.096	0.151
	Change_02	-0.030	0.025	.196*	0.036	0.102	0.113	0.069	-0.051	-0.136	0.111	0.066	-0.002	0.124	.201*
	Change_03	0.115	0.160	0.053	0.009	0.092	.230**	0.135	.212*	0.048	0.007	0.112	0.151	0.183	.199*
	Change_04	.246*	.207*	0.136	0.107	.329**	0.176	0.121	-0.095	-0.114	0.084	-0.066	-0.134	-0.182	-0.106
	Change_05	0.154	.240*	-0.140	0.030	.237*	0.046	.267*	0.007	0.002	-0.112	-0.135	-0.100	-.214*	-.212*
	Change_06	0.178	.311**	-0.009	-0.001	.273**	0.035	0.160	0.093	-0.007	0.035	-.277**	-.250**	-.325**	-.294**
	Change_07	-0.007	-0.011	0.020	0.020	0.135	0.072	0.008	-0.077	-0.138	-0.160	-0.106	-.205**	0.000	-0.073
Design-related	Change_08	0.162	0.098	-0.161	-.197*	0.135	0.063	0.097	0.146	-0.054	-0.023	-0.102	-0.140	-0.109	-0.162
	Change_09	.216*	0.123	0.118	0.002	.266**	0.010	0.017	-0.097	-0.081	0.061	0.008	-0.068	-0.079	-0.106
	Change_10	0.157	.211*	0.025	0.100	.315**	.215*	.238*	0.092	0.005	0.007	-0.047	-0.050	-0.111	-0.156
	Change_11	0.091	0.130	0.046	0.081	.328**	0.185	0.107	0.033	0.079	0.022	-0.062	-0.105	-0.120	-0.132
	Change_12	0.179	0.154	-0.138	-0.074	.214*	-0.144	0.071	0.034	0.001	-0.058	-.308**	-0.062	-.286**	-.307**
	Change_13	.270**	.245**	0.053	0.033	.303**	0.115	0.096	0.046	0.026	0.032	-.209**	-0.183	-.302**	-.313**
	Change_14	0.185	.237**	-0.043	0.149	0.151	-0.042	0.060	0.012	-0.025	-0.003	-0.127	-0.043	-.324**	-.214*
	Change_15	0.051	0.168	0.003	0.107	.307**	0.101	0.200	0.098	-0.066	-0.025	-0.150	0.022	-.201*	-.208*
	Change_16	.275**	.263**	-0.002	-0.050	.347**	0.078	0.130	-0.074	-0.039	0.060	-0.181	-.213**	-.250**	-.263**
	Change_17	0.127	0.131	0.067	-0.021	.325**	0.045	0.114	-0.072	-0.025	-0.027	-0.131	-.215**	-0.180	-.243**
Contractor-related	Change_18	-0.004	-0.069	0.085	-0.073	.215*	.222*	0.027	0.034	-0.021	0.116	0.011	-0.016	-0.034	0.043
	Change_19	-0.070	-0.011	0.088	-0.069	0.062	0.139	0.081	0.059	-0.028	0.130	-0.022	0.060	-0.004	0.073
	Change_20	0.173	0.160	0.007	-0.070	.277**	0.003	0.010	-0.073	0.012	-0.078	-0.093	-0.129	-.187*	-.215*
	Change_21	0.067	0.024	0.083	-0.099	0.073	.203*	0.131	0.039	-0.085	0.025	0.031	-0.034	0.123	0.109
	Change_22	0.104	0.099	0.028	-0.118	.245**	0.039	0.040	0.010	-0.089	-0.040	-0.123	-.222**	-.239**	-.253**
Process-related	Change_23	.231*	0.180	0.015	-0.113	.290**	0.129	0.097	0.017	-0.098	-0.001	-0.130	-0.157	-.380**	-.383**
	Change_24	0.110	0.097	-0.060	-0.013	.386**	0.157	.245*	0.146	-0.056	0.184	-.243**	-0.062	-.305**	-.316**
	Change_25	.203*	0.128	0.053	-0.046	.386**	0.058	0.053	0.007	-0.074	0.066	-0.138	-0.049	-.363**	-.302**
	Change_26	.232*	.242*	0.085	-0.137	.385**	0.052	0.149	0.039	-0.024	0.135	-0.140	-0.014	-.289**	-.332**
	Change_27	.278**	.260**	-0.017	-0.116	.269**	-0.009	.234*	0.073	0.022	0.061	-.211*	-0.093	-.382**	-.441**
	Change_28	0.079	0.123	0.048	0.019	.331**	.189*	0.097	0.049	-.283**	0.142	-0.033	-0.039	-.237*	-.187*
Site-related	Change_29	0.129	0.137	0.140	0.059	.228*	0.047	0.125	0.175	-0.101	0.080	-0.144	0.072	-0.125	-0.122
	Change_30	0.129	0.111	0.069	-0.063	0.110	0.017	0.124	.221*	-0.115	-0.006	-0.152	0.071	-0.078	-0.143
	Change_31	0.192	0.142	0.058	-0.042	-0.036	0.121	0.149	.222*	-0.052	-0.078	-0.039	0.020	-0.116	-0.153
External-related	Change_32	0.109	-0.014	0.109	-0.064	.224*	0.129	-0.072	-0.024	-0.140	0.165	-0.023	-0.134	-0.050	-0.025
	Change_33	0.046	0.006	0.109	-0.087	.312**	.202*	0.087	0.153	-0.076	0.173	-.194*	0.031	-0.179	-0.135
	Change_34	0.012	0.037	0.024	-0.020	0.162	0.109	0.129	0.179	-0.079	-0.033	-.204*	-0.002	-0.133	-0.141
	Change_35	0.158	0.165	0.046	-0.015	.215*	0.088	0.135	.243*	0.063	-0.064	-0.027	.215*	-0.022	-0.106
	Change_36	0.093	-0.018	0.154	0.127	.186*	.257**	-0.038	0.058	-0.027	0.087	-0.028	0.016	-0.109	-0.047

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 2 - Correlation Analysis Matrix

majorly applied to variable measured in a ratio scale, while Spearman's rho is normally applied when having variables measured in categorical or ordinal scale, it was decided to use a Pearson product-moment correlation (Pallant, 2013).

For this correlation analysis a double-sided approach was used because the direction of the relationship is not the focus here since what we are trying to find is the relation in itself. This can be observed in Figure 15. The hypothesis to be examined suggests the existence of a relation between Flexibility Recourses and Design Change causes. The null hypothesis in this research would be the lack or absence of a relation between the two variables.

The program to be used will be SPSS, the correlation will be done by a bivariate correlation using Pearson's correlation coefficient. The output of correlating all 36 change statements with the 14 flexibility ones was a correlation matrix. This correlation matrix had a total of 504 correlations between variables from which 107 had a significant correlation, this can be observed in Table 1 where significant correlations are highlighted.

There are two types of significant correlations, significance of $p \leq 0.05$ and significance of $p \leq 0.01$. The significance indicates the risk of labelling the existence of a correlation between variables without this correlation existing. That is why we search for those correlations which have less than 5% of this risk. When significance level is under 1% it is considered to be substantially high, and the relationship between these variables is not only in the sample but can be considered general. The general matrix and its explanation on how to read it can be found in Appendix G.

In this case having 107 correlations of high significance makes it difficult to analyse every relationship between variables. Thus, it was decided to carry out a Factor Analysis with the aim to reduce the correlations. The process and outcome of this analysis will be explained further in the next section.

4.4 Factor Analysis

Factor analysis is not designed for testing a hypothesis but is used as a data reduction technique. Its process consists of taking a large set of variables and finding a way to reduce it. It creates groups among inter-correlations of the variables, which are impossible to do by eye, and creates a new and smaller set of factors or components. The aim of factor analysis is to reduce and refine the large number of variables to a smaller and more manageable number, before carrying out another analysis to the set. Within the term Factor Analysis there are several different techniques contemplated. The most distinctive techniques are two: one is named Principal Components Analysis (PCA) and another one Factor Analysis (FA) (Pallant, 2013). These two, attempt to produce a smaller set of linear combinations of the original variables, in such a way that it grasps the maximum variability within this pattern of correlations. The difference between these two techniques lies in the fact that Principal Components Analysis the variables are transformed into a smaller set, but the variance is fully used. However, Factor Analysis technique an estimation is done via a mathematical model where only the shared variance is taken into account (Pallant, 2013).

For this research the Principal Components Analysis will be carried out, since Stevens (2012) argues that is simpler in a mathematical way and some problems associated with Factor Analysis can be avoided. In their research Tabachnick and Fidell (1996) conclude that if an empirical summary of the set of variables is wanted, the best choice is Principal Components Analysis. The analysis will be executed in SPSS as the correlation analysis was done. The aim of using the Principal Components Analysis approach was to reduce the quantity of variables in the data set since, as explained in the last section, the Correlation Matrix reflected 107 significant correlations which is a very big number to analyse. The Principal Component Analysis was done for each of the categories for design change causes and for each of the flexibility recourses. This meaning that from each category or recourse only one component was extracted. In the case of some flexibility recourses which only had one original variable, that variable was left was a component. The extraction value for the analysis was set on the fixed factors instead of eigenvalue, since the latter one would have more than one component extracted in some categories and did not fulfil the purpose of diminishing the number of variables in the analysis. Given that only one component was extracted, a rotation was not needed. The outcome of this analysis were 6 components extracted as Design Change Causes and 8 components for Flexibility Recourses. These components are extracted due to the percentage of variance and are not the original variables, but a new component based on those original values was created.

After finalizing the Factor Analysis step and having the new components extracted, a correlation analysis was done between these new components. The analysis showed 48 correlations between the components, and among these 10

		Flexibility Recourses							
		Incremental Planning	Iterative Planning	Continuous Locking	Contingency Planning	Buffers	Late Locking	Short feedback loops	Cross functional and multi-disciplinary teams
Design Change Causes	Client-related	.316**	0.020	.395**	0.055	0.050	0.028	-0.188	-0.156
	Design-related	0.181	0.053	.392**	0.111	0.030	-0.071	-0.195	-.344**
	Contractor-related	0.151	-0.041	.268**	0.140	-0.023	0.048	-0.122	-0.144
	Process-related	.270**	-0.040	.420**	0.157	0.070	0.104	-0.148	-.447**
	Site-related	.202*	0.051	0.118	0.098	0.159	-0.025	-0.021	-0.133
	External-related	0.063	-0.017	.287**	0.197	0.027	0.081	-0.102	-0.163

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 3 - Correlation of Components extracted from Principal Correlation Analysis

significant relations. In Table 2 the results are presented the correlation boxes highlighted are those which have a significant correlation. From a first glance, it can be observed that these new correlations were already significant in the correlation matrix from the first correlation analysis, except for one. The correlation between Site-related Design Change Causes and Incremental Planning was not found significant in the first correlation analysis carried out. This could be explained by the fact that the new component is created as a summary of the different variables which conformed the category originally and is not one of the original variables. Given that the new component is based on the variance of the original values, it can happen that the new components have significance correlations which were not there before. However, it must be noted that this correlation between Site-related Design Change Causes and Incremental Planning is the only correlation in the new Matrix which has a significance of $p \leq 0.05$ instead of a significance of $p \leq 0.01$ as the rest. Based on what was explained in the previous section this means that the risk of being labelled a significant correlation when it is not is bigger than the rest of the significant correlations in the new matrix. Nonetheless, the risk is very low and is interpreted as a significant relation. In the next section the results are presented, and the analysis explained.

4.5 Results of the analysis

In this section the correlations of the Principal Component will be analysed and discussed considering the significant correlations of the original variable matrix. The correlations of the original variables will aid in understanding the different factor that influence the correlation of the components. In the tables below it can be observed the different characteristics of the significant correlations found. Here it can be observed the main correlation of the components extracted with Factor Analysis and the original variables significant correlations as the predominant factor within these new components.

Incremental Planning and Client-related Design Change causes

The first significant correlation which appears in Table 4 (A1) between “A detailed schedule is not made at the beginning of the process, but a weekly scheduling exercise is carried out” and “There are omissions of the scope given by the client” has a positive correlation, meaning that when one increases by one unit the other increases with 0.246 unit, and the same happens when they decrease. The direction of this correlation could not be determined since there is a lack of a logical reason behind it. The client-related design change causes do not have a relation with the project management aspects as to be influenced by it. The causality behind the relationship was also not determined without the logical reasoning behind it.

The A2 example has a positive correlation, so in case one increases by a unit the other will increase 0.207 unit and same will apply when the variables decrease. In this case, as the one before, the direction and causality of this relationship was not determined.

			Correlation	Strength	Significance	Relationship	Direction
A.	Incremental Planning	Client-related	0.316	Medium	0.0068	+	→
A1.	A detailed schedule is not made at the beginning of the process, but a weekly scheduling exercise is carried out.	There are omissions of the scope given by the client	0.246	Weak	0.011	+	
A2.	A detailed schedule is not made at the beginning of the process, but a monthly scheduling exercise is carried out.	There are omissions of the scope given by the client	0.207	Weak	0.034	+	
A3.		The contract type chosen was not appropriate for the project	0.240	Weak	0.032	+	
A4.		The brief given by the client is unclear	0.311	Medium	0.003	+	→

Table 4 - Incremental Planning and Client-related Design Change Causes Analysis

The next correlation, A3, has a positive correlation and the two variables will increase or decrease together having a 1 to 0.240 ratio. This means that the more flexibility recourse is used the more causes of design change there will be. The direction of this correlation could not be determined since no logical connection was found between the cause of design change and flexibility recourses in the management of the project.

The last correlation in Table 3 has a positive correlation, being the case that the two variables will increase or decrease together having a 1 to 0.311 ratio. Meaning that if the flexibility recourse increases so will the causes of design change. The direction for this correlation will be assumed, taking into account that the increase in the use of a monthly scheduling exercise, the more the client will not feel pressured to correct the unclear aspects of the project brief. However, this is only an assumption.

The overall analysis within Incremental Planning and Client-related causes of design change determines that there is a relationship between these two variables. The direction of this relationship will mean that flexibility recourses are affecting the design change causes. This was determined since the only correlation which direction was determined was A4 being this the only medium strength relationship and the one with higher significance. The cause and effect of this relationship cannot be explained directly by these two variables. However, the fact that incremental planning increases or decreases in the same ratio with relation to change causes, creates an undesired effect on the proactive use of flexibility enablers.

Incremental Planning and Process-related Design Change causes

In Table 5 it can be observed the component correlation (B) and the significant correlations (from B1 to B6) between the variables that create the components correlated in B. First an analysis of the significant correlations of the original variables will be done to understand the correlation between components at a bigger scale.

			Correlation	Strength	Significance	Relationship	Direction
B.	Incremental Planning	Process-related	0.270	Weak	0.045	+	→
B1.	A detailed schedule is not made at the beginning of the process, but a weekly scheduling exercise is carried out.	There is a poor project organizational structure	0.231	Weak	0.017	+	
B2.		There is a lack of coordination and communication	0.203	Weak	0.037	+	→
B3.		There are problems in the availability of information within the project	0.232	Weak	0.018	+	→
B4.		There are multiple/not aligned schedules in the project	0.278	Weak	0.004	+	→
B5.		There are problems in the availability of information within the project	0.242	Weak	0.013	+	→
B6.		There are multiple/not aligned schedules in the project	0.260	Weak	0.007	+	→

Table 5 - Incremental Planning and Process-related Design Change Causes Analysis

Firstly, in B1 a positive correlation can be seen where one variable increases a unit the other variable will increase 0.231 and will decrease together in the same ratio. The direction of this correlation has not been able to be determined since no plausible reasoning has been thought of. It cannot be assumed that the organizational structure influences the use of a weekly scheduling exercise, nor can it be that use of incremental monthly planning affects the project organizational structure.

Secondly, in B2 there is a positive correlation meaning that both variables increase and decrease together in a 1 to 0.203 ratio. The direction of the correlation is assumed to be that the lack of detail of the planning at the beginning of the project and adding details and information into the new plan in a weekly basis can affect the coordination and communication within the project. These could be due to the increase of plan versions that will be part of the project and its constant update can create an increase on the lack of coordination in the project team and problems in the communication. This meaning that the more this flexibility recourse is used the more causes of design change will arise in the project.

Thirdly, in B3 a positive correlation can be observed between variables having an increase and decrease ratio of 1 to 0.232. Since the causes of change have a connection with the way the project is managed, it can be assumed that the level of detail of the planning at the beginning of the project can create problems in the availability of information within the project. The cause and effect of this relationship between variables cannot be determined directly from these two variables.

The fourth correlation is a positive one being the fluctuation ratio of 1 to 0.278. The direction of this correlation is assumed to be that because there is an increase on the use of non-detailed planning, and weekly working on incrementing the detail in the planning, can have an effect in increasing the quantity of schedules and the lack of alignment between them. This could be because each week a new version of the planning will be made, and without a proper organization this may get confusing to know which is the latest and valid plan.

As seen in Table 4 section B5 has a positive correlation, being the case that the two variables will increase or decrease together having a 1 to 0.242 ratio. The direction will be defined as it was the case of B3 since the only difference lays in the frequency of the planning update. The same applies to B6, where the difference with B4 is between monthly or weekly updates. The direction will be the same as the case of B4.

Finally, the general correlation of these complements is positive. The direction follows the logic that the flexibility recourse affects the design change cause.

Incremental Planning and Site-related Design Change causes

This correlation between components created a significant correlation which was not found in the correlations between the original variables. Although this is a possibility when working with Factor Analysis and Principal Component Analysis, this was the only correlation that appeared without having correlations within the original variables. The reason for it is because the components are created by a summary of the different variables and their variance, so a new component is created from the different variables. It was noted that within the original correlations one variable had a significance of 0.05025, “there are differing site conditions during the project than planned” correlated with “A detailed schedule is not made at the beginning of the process, but a weekly scheduling exercise is carried out”, which is almost a significant

correlation, since $p \leq 0.05$. Even though that could be the reason why this correlation appeared, the real reason lies within the mathematical model behind the Factor Analysis.

			Correlation	Strength	Significance	Relationship	Direction
C.	Incremental Planning	Site-related	0.202	Weak	0.045	+	

Table 6 - Incremental Planning and Site-related Design Change Causes Analysis

This correlation is positive and the increase or decrease ratio between variable is of 1 to 0.202. The direction of the correlation will be done by assumptions. The different variables of site related causes are the following: “Changes in the site layout and/or access to it arise during the project”, “there are differing site conditions during the project than planned”, and “There are changes in the ground conditions during the project”. Since none of these variables of design change causes do not have a connection with the project management, there is not a logical relation between them. Thus, the direction of the relation will not be determined. There is no causality that could be thought for arguing the direction of the relationship between these two variables either.

Continuous Locking and Client-related Design Change causes

In Table 7 it can be appreciated the different correlations of the original variables (from D1 to D3) which will give some background to be able to understand the components correlation (D).

			Correlation	Strength	Significance	Relationship	Direction
D.	Continuous Locking	Client-related	0.395	Medium	0.000	+	
D1.	Decisions in the project are continuously postponed until the required information is available.	There are omissions of the scope given by the client	0.329	Medium	0.000	+	
D2.	Decisions in the project are continuously postponed until the required information is available.	The contract type chosen was not appropriate for the project	0.237	Weak	0.027	+	
D3.	Decisions in the project are continuously postponed until the required information is available.	The brief given by the client is unclear	0.273	Weak	0.007	+	

Table 7 - Continuous Locking and Client-related Design Change Causes

To start with the first correlation, D1, it can be observed that the correlation is positive with a ratio of 1 to 0.329. The direction for this correlation could not be determined since no reasoning whatsoever was found. Thus, no direct causality was found, highlighting the possibility of an external factor being the variable affecting this relationship.

The second correlation, D2, is a positive correlation and the variables increase or decrease with a ratio of 1 to 0.237. The direction of the correlation was not assumed. It seems unlikely that there is a direct causality for the correlation between the contract type not being appropriate for the project and continuously postponing making decisions, given that the contract is decided previously to the project management approach.

Ultimately, the D3 correlation has a positive relationship between the variables with a ratio of 1 to 0.273. The direction of this correlation was not determined. The causality of the relationship between these two variables was not determined since the causes of change do not have any relation with the project management approach, making no logical assumption valid for causality or direction of it.

In conclusion, the correlation between Continuous Locking and Client-related Design Change causes will be positive with a ratio of 1 to 0.395. The direction of the correlation will not be defined, and the cause and effect of this relationship either, since there is no logically direct reason that could be thought.

Continuous Locking and Design-related Design Change causes

As it can be observed in Table 8, the first correlation between variables in this category is positive and with a ratio of 1 to 0.266. The direction of the correlation could be assumed to be that the more postponement of the decisions there are in the project the more modifications to the design that can be done during the project. Therefore, it was decided to assume a direction where the flexibility recourse affects the design change cause.

Moreover, the E2 correlation is positive with a ratio of 1 to 0.315. The direction of the correlation is assumed to be that the more decisions are continuously postponed in projects the more design errors appear in the project. However, the causality behind this relationship cannot be explained directly with these two variables.

The E3 correlation is positive, meaning that when one variable increases the other one will increase as well. The same happens when one variable decreases. These fluctuations will be done in a ratio of 1 to 0.328. The direction of this correlation follows the same logic as the one before since omissions and errors are treated very similarly in the design of projects. The more decision-making process is postponed the more omissions in the design will appear in the project.

The E4 correlation is positive with a ratio of 1 to 0.214. The direction of the correlation will be assumed to be that the increase of the flexibility recourse will have an effect on the design change causes, increasing them in a 0.214 of a unit.

			Correlation	Strength	Significance	Relationship	Direction
E.	Continuous Locking	Design-related	0.392	Medium	0.000	+	→
E1.	Decisions in the project are continuously postponed until the required information is available.	There were modifications to the design once the project started	0.266	Weak	0.004	+	→
E2.		Design errors appear during the project	0.315	Medium	0.001	+	→
E3.		Design omissions are encountered in the project	0.328	Medium	0.001	+	→
E4.		The project has an outdated design	0.214	Weak	0.029	+	→
E5.		Information from any given source provided to designers is inadequate	0.303	Medium	0.002	+	→
E6.		There are discrepancies between contract documents in the project	0.307	Medium	0.001	+	→
E7.		There is a lack of awareness of regulations or requirements of local authorities	0.347	Medium	0.000	+	→
E8.		The project has Incomplete drawings	0.325	Medium	0.000	+	→

Table 8 - Continuous Locking and Design-related Design Change Causes Analysis

Furthermore, the E5 correlation being positive the two variables increase and decrease together with a ratio of 1 to 0.303. The direction of this correlation will be interpreted as the flexibility recourse affects the design-related change cause by increasing it in the proportion already mentioned. The causality of this correlation could not be thought of, so it was not determined.

The next correlation, E6 is again a positive correlation with a ratio of 1 to 0.307. The direction of this correlation is based in the assumption that when increasing the use of postponing decisions until the information needed is available, could give the opportunity to find the discrepancies between contract documents, as the information that is available will be thoroughly reviews in a continuous manner.

The E7 correlation is positive and has a ratio of 1 to 0.347. The direction of the correlation was not assumed, neither the cause nor effect of this relationship since no direct connection could be thought of.

Lastly, the E8 correlation continues being a positive correlation, with a ratio of 1 to 0.325. The assumption behind the direction of the correlation was the following: the more postponement of decision making the more incomplete drawings there are in a project, until the information required is available.

Consequently, the E correlation between these two components, continuous locking and design-related causes of change, has a positive correlation with a ratio of 1 to 0.392, which has a medium strength based on Cohen (2013). The direction of this correlation is based on the directions of the original variables' correlation. It can be said that with an increase of the use of flexibility recourse of continuous locking there is an increase in the design-related change causes.

Continuous Locking and Contractor-related Design Change causes

In Table 9 we can observe there are three significant correlations between the original variables that can give us the necessary information to understand the correlation between these two components extracted from the Principal Component Analysis.

			Correlation	Strength	Significance	Relationship	Direction
F.	Continuous Locking	Contractor-related	0.268	Weak	0.007	+	→
F1.	Decisions in the project are continuously postponed until the required information is available.	There are requests to use available materials in the market	0.215	Weak	0.024	+	→
F2.		There are incomplete plans and specifications in the project	0.277	Weak	0.003	+	→
F3.		There are insufficient working drawing details for the project	0.245	Weak	0.009	+	→

Table 9 - Continuous Locking and Contractor-related Design Change Causes Analysis

The first correlation F1 is a positive correlation with a ratio of 1 to 0.215. The direction of the correlation is assumed to be that by increasing the postponement of decisions in the project there could be an increase of requests to use materials available in the market instead of the materials in the original design. These could be since postponing acquiring the materials could lead to certain materials not being available anymore, or the discovery of a more economic/faster delivery product with the same requirements.

The second correlation F2 is as well a positive correlation with a ratio of 1 to 0.277. The assumption to establish the direction of this correlation was that when using the flexibility recourse of postponing decisions until information needed is available there can be an increase in the incompleteness of plans and specifications in the project. This incompleteness should be until the information needed becomes available whatever that time frame is.

The last correlation, F3, is a positive correlation with a ratio of 1 to 0.245. The direction of the correlation will be assumed to be towards the cause of design change, being an increase or decrease of postponing the decision-making process there would have the same effect on the insufficiency of drawing details for the project. This could be explained by the fact that postponing decisions create delays in the creation of detail drawings, since the information needed to continue is not available in that specific moment. When the information required for the decisions to be made, the drawings will be fulfilled.

In conclusion, the correlation between continuous locking and contractor-related design change causes is a positive one. Based on the other correlations, the direction should be the one shown in Table 8. These is understandable if the assumptions made are that for an increase in the use of flexibility recourses there will be contractor-related causes of change increasing in the project.

Continuous Locking and Process-related Design Change causes

In this section the correlation of these two components will be analysed. For this, firstly the correlation between the original variables that conform the components will be analysed and used as a base to understand how the correlations works.

In the first correlation (G1) it can be observed that is positive and has a ratio of 1 to 0.290. The direction of the correlation of these two variables was not determined since no possible reason was thought of. Consequently, no direct causality has been found.

The second correlation G2 has a direction which flexibility recourses affect the design change causes, being the ratio of 1 to 0.386. This is because the decisions in the management of the project can have that effect, even if no causality was assumed by the lack of a logical explanation behind it.

G3 is a positive correlation with a ratio of 1 to 0.386. Here it is assumed that an increase of lack of coordination and communication could be the effect of an increase in the use of the resource of postponing the making of decisions until the information required is available. Communication and coordination may be affected by the constant postponing of decisions, making the process not run as smoothly as it would be otherwise.

The fourth correlation (G4) is positive as well with a ratio of 1 to 0.385. The direction of this correlation was determined to be that the flexibility recourse affects the process-related design change causes. However, since no logical reasoning was found to explain the causality of this relationship, it was not determined.

Fifth correlation of Table 10 presents the correlation between the postponement of decision-making until the required information is available and the existence of multiple and not aligned schedules in the project. These have a positive correlation and a ratio of 1 to 0.269. The relation between the variables is evident, however the causality and direction of the same has not been established since no logical explanation was found.

For last, the G6 correlation, has a positive correlation. The assumption is made that if there is an increased overlap between design and construction phase it could be an effect of an increase in decisions being postponed. Because the postponement of making decisions, can create a design phase continued until parts of construction phase have already started. It can be said that when the decision-making postponement increases in 1 unit, an overlap in design and construction phase will increase in 0.331 unit.

			Correlation	Strength	Significance	Relationship	Direction
G.	Continuous Locking	Process-related	0.420	Medium	0.000	+	→
G1.	Decisions in the project are continuously postponed until the required information is available.	There is a poor project organizational structure	0.29	Weak	0.002	+	
G2.		The project experienced unpredictable circumstances during construction	0.386	Medium	0.000	+	→
G3.		There is a lack of coordination and communication	0.386	Medium	0.000	+	→
G4.		There are problems in the availability of information within the project	0.385	Medium	0.000	+	→
G5.		There are multiple/not aligned schedules in the project	0.269	Weak	0.004	+	→
G6.		There is an overlapping of design and construction phase	0.331	Medium	0.000	+	→

Table 10 - Continuous Locking and Process-related Design Change Causes Analysis

Continuous Locking and External-related Design Change causes

The first correlation of this category is a positive correlation of 0.224. The direction of this correlation could not be determined since no logical explanation was conveyed. Due to this causality was not defined either.

The second correlation is also positive and has a ratio of 1 to 0.312. For this correlation, same as the previous one, the direction was not defined, neither the causality of it.

Thirdly, the H3 correlation is a positive correlation of 0.215. The direction of this correlation could not be assumed since no sensible reasoning can explain it.

Lastly, the fourth correlation is a positive correlation with a ratio of 1 to 0.186, a weak correlation. Even though a relationship was established, its direction could not be determined. Thus, the causality has not been defined either.

Overall, the correlation for this category is weak and positive, but no direction or causality could be discerned that explains the relationship. The external-related causes of design change do not have a logical connection with the management of the project in order to be affected by it, making the direction of the relationship and its causality unable to define.

			Correlation	Strength	Significance	Relationship	Direction
H.	Continuous Locking	External-related	0.287	Weak	0.004	+	
H1.	Decisions in the project are continuously postponed until the required information is available.	There are changes in economic conditions during the project	0.224	Weak	0.019	+	
H2.		Changes arise during the project regarding government policy/issues	0.312	Medium	0.001	+	
H3.		The project suffered with severe weather conditions	0.215	Weak	0.0250	+	
H4.		There are unexpected changes in material availability during the project	0.186	Weak	0.049	+	

Table 11 - Continuous Locking and External-related Design Change Causes Analysis

Cross functional and multi-disciplinary teams and Design-related Design Change causes

In this section the correlation between the components of cross functional and multi-disciplinary teams and design-related causes of design change will be analysed. The analysis will be done per correlation between the original variables, so as to understand where the overall correlation is coming from.

The first correlation between the variables “there is an involvement of all parties and disciplines in the project working together as a team” and “the project has an outdated design” has a negative correlation of 0.286, which means that when one variable increases 1 unit the other will decrease 0.286 unit. The direction of this correlation is assumed to be that when the involvement of all parties in the project working together as a team increases the outdated design of the project decreases. Due to the increase of all parties involvement in the teamwork, the communications between parties will increase and improved. And better communications means that the project having an outdated design should decrease, since it is easier for practitioners to realize that it is happening.

The second correlation is between the variables “there is an involvement of all parties and disciplines in the project working together as a team” and “information from any given source provided to designers is inadequate” has a negative correlation of 0.302, meaning that when one variable increases 1 unit the other will decrease 0.302 unit. The direction of this correlation is assumed to increase the involvement of all parties in the work team and decrease the inadequacy of the information provided to designers. The increase of the multi-disciplinary team reduces fragmentation problems, and with that communication should improve. When improving these, the information that is provided to designers would be from first-hand, since they are involved in the team.

The third correlation is between the variables “there is an involvement of all parties and disciplines in the project working together as a team” and “designer team is not involved during construction phase” has a negative correlation of 0.324. The direction of this correlation will be assumed. Since the involvement of the different parties in the multi-disciplinary team is increased the non-involvement of designer team in construction phase will decrease. Since the design team is now part of the general team, they will be more involved with the construction phase even if it is not their direct responsibility.

The fourth correlation is between the variables “there is an involvement of all parties and disciplines in the project working together as a team” and “there are discrepancies between contract documents in the project”, which has a negative correlation of 0.201. The direction of this correlation assumes an increase in the multi-disciplinary team and a decrease of discrepancies between contract documents. Because when parties of a project work together as a team, the communication of information is done in a less fragmented way, making those possible discrepancies or errors are found faster and solved easier than a fragmented work team.

			Correlation	Strength	Significance	Relationship	Direction
I.	Cross functional and multi-disciplinary teams	Design-related	0.344	Medium	0.001	-	→
11.	There is an involvement of all parties and disciplines in the project working together as a team.	The project has an outdated design	0.286	Weak	0.003	-	→
12.		Information from any given source provided to designers is inadequate	0.302	Medium	0.002	-	→
13.		Designer team is not involved during the construction phase	0.324	Medium	0.001	-	→
14.		There are discrepancies between contract documents in the project	0.201	Weak	0.038	-	→
15.		There is a lack of awareness of regulations or requirements of local authorities	0.25	Weak	0.008	-	→
16.		The project has an outdated design	0.307	Medium	0.002	-	→
17.	The information is shared and available for all the different parties in the project.	Information from any given source provided to designers is inadequate	0.313	Medium	0.001	-	→
18.		Designer team is not involved during the construction phase	0.214	Weak	0.025	-	→
19.		There are discrepancies between contract documents in the project	0.208	Weak	0.032	-	→
110.		There is a lack of awareness of regulations or requirements of local authorities	0.263	Weak	0.005	-	→
111.		The project has incomplete drawings	0.243	Weak	0.010	-	→

Table 12 - Cross functional and multi-disciplinary teams and Design-related Design Change Causes Analysis

The fifth correlation is between the variables “there is an involvement of all parties and disciplines in the project working together as a team” and “there is a lack of awareness of regulations or requirements from local authorities”. This correlation is negative with a ratio of 1 to 0.250, meaning that when one variable increases by 1 unit the other one will decrease by 0.250 unit. The direction of this correlation assumes that an increase of multi-disciplinary teamwork will decrease the lack of awareness of regulations and requirements from local authorities. The communication improvement when the different parties of the project are working as a team, makes the flow of information easier to accomplish and faster. Being this the case, the lack of awareness of regulations and requirements should diminish in some proportion.

The sixth correlation is a negative one with a ratio of 1 to 0.307, being between the variables “the information is shared and available for all the different parties in the project” and “the project has an outdated design”. The direction of this correlation will be under the assumption that an increase in the information being shared and available for everyone in the project will decrease the project having an outdated design. The flow and availability of information throughout the team should help diminish the probabilities of using an outdated design.

The seventh correlation between “the information is shared and available for all the different parties in the project” and “information from any given source provided to designers is inadequate” has a negative correlation of 0.313. The direction was selected due to the assumption of an increase in information being shared by everyone in the team and increasing the availability of the information, should have an effect of decrease in the inadequacy of the information provided to the designers. Since the designers should be able to get access to all the information of the project, the probability of getting inadequate information is substantially less.

For the eighth correlation found, being negative with a ratio of 1 to 0.214, somewhat the same reasoning applies. An increase of “the information is shared and available for all the different parties in the project” will generate a decrease of “designer team is not involved during construction phase”. Because the information is available to everyone in the project. The design team will be able to know whatever is happening in the construction phase. This will become an advantage for improving information distribution and communication between the team members.

The ninth correlation is negative with a ratio of 1 to 0.208. An increase of availability and sharing of information between the different parties on the project will make the discrepancies between contract documents decrease. This is due to an improvement in communication between the parties, and the constant availability of information to everyone in the work team. This diminishes the probabilities of discrepancies appearing and not being caught on time.

The tenth correlation continues the same reasoning as the majority of this section. Being a negative correlation, an increase of 1 unit of the availability and sharing of information between the different parties on the project will make the lack of awareness on regulations and requirements from local authorities decrease by 0.263 unit. Since the information is available to everyone within the project, communication between the parties is much more efficient. Within the entire team the chances of not being aware of regulations and requirements from local authorities decreases greatly.

Lastly, the eleventh correlation in this section is negative with a ratio of 1 to 0.243. Assumptions are made about an increase in information sharing and availability creating a decrease on incomplete drawings in the project. If the information is shared and available by all the parties, the different parties can easier reach the information needed for completing the drawings of the project. As well, the realization of this problem can be corrected in a faster and more efficient way, due to the enhanced communication and flow of information within the team.

Consequently, section the correlation between the components of cross functional and multi-disciplinary teams and design-related causes of design change is negative. When there is an increase of 1 unit in cross functional and multi-disciplinary teams there is a decrease of 0.344 unit in design-related change causes.

Cross functional and multi-disciplinary teams and Process-related Design Change causes

The first correlation has a negative correlation with a ratio of 0.380. The direction of the correlation assumes that when there is an increase in the involvement of all parties within the project team there will be a decrease of the poor project organizational structure. Since the involvement of all parties in the project team can only improve the organizational structure of the project.

The second correlation is negative with a ratio from 1 to 0.305. And the direction relies on an increase of the involvement of all the parties within the project team and a decrease of the appearance of unpredictable circumstances during construction. The more people and disciplines involved in the project team, the more information of different areas that will be shared, decreasing the possibilities of experts not predicting the possible circumstances that will convey a risk in the project during construction.

The third correlation is 0.363 negative, meaning that when variable increases the other one will decrease. The assumption for determining the direction of this correlation lies in the increasing involvement of all parties and disciplines within the project team and the decreasing lack of communication and coordination. For people to be able to work together in a multi-disciplinary team the coordination and communication should improve. By having the different parties working together as a team, the communication and coordination between practitioners within the team will improve.

The fourth correlation is negative and 0.289. The direction of the correlation will increase the teamwork conformed by all the parties in the project and decrease the problems of the availability and sharing of information. Due to the different parties working together the communication will improve. Apart from this when communications improve and because the practitioners are all working together as a team, the information will be easier to share within team members and will be available for everyone to access.

The fifth correlation is also negative but has a ratio of 1 to 0.382. The direction of the correlation goes towards the change cause, since if there is an increase of the involvement of all parties and disciplines within the project team, this creates a decrease in the multiple and not aligned schedules of the project. Because the different parties are working together towards the same goal, the communication will increase and become constant, which will aid in refining one only schedule

for everyone to be in the same page. When there is a decrease of the involvement of parties working together, there is a rise in fragmentation leading to an increase of misunderstandings and multiplication of schedules without knowing which is the latest version or is not updated to the last modification.

The sixth correlation is negative and has a ratio of 1 to 0.237. However, no direction was assumed. It seems unlikely that a direct correlation exists between the involvement of all parties working together as one team and an overlapping of design and construction phase.

The seventh correlation found is negative and has a ratio of 0.383. The direction is assumed to be towards an increase on the sharing and availability of the information within a project and a decrease of a poor organizational structure within the project.

The eighth significant correlation is found between the “information is shared and available for all the different parties in the project” and “the project experienced unpredictable circumstances during construction”. The correlation found is a negative 0.316. Here it is assumed that an increase of the sharing and availability of information for the different parties

			Correlation	Strength	Significance	Relationship	Direction
J.	Cross functional and multi-disciplinary teams	Process-related	0.447	Medium	0.000	-	→
J1.	There is an involvement of all parties and disciplines in the project working together as a team.	There is a poor project organizational structure	0.380	Medium	0.000	-	→
J2.		The project experienced unpredictable circumstances during construction	0.305	Medium	0.001	-	→
J3.		There is a lack of coordination and communication	0.363	Medium	0.000	-	→
J4.		There are problems in the availability of information within the project	0.289	Weak	0.002	-	→
J5.		There are multiple/not aligned schedules in the project	0.382	Medium	0.000	-	→
J6.		There is an overlapping of design and construction phase	0.237	Weak	0.011	-	

Table 13 - Cross functional and multi-disciplinary teams and Process-related Design Change Causes

J7.	The information is shared and available for all the different parties in the project.	There is a poor project organizational structure	0.383	Medium	0.000	-	→
J8.		The project experienced unpredictable circumstances during construction	0.316	Medium	0.001	-	→
J9.		There is a lack of coordination and communication	0.302	Medium	0.001	-	→
J10.		There are problems in the availability of information within the project	0.332	Medium	0.000	-	→
J11.		There are multiple/not aligned schedules in the project	0.441	Medium	0.000	-	→
J12.		There is an overlapping of design and construction phase	0.187	Weak	0.048	-	

Table 14 - (continuation) Cross functional and multi-disciplinary teams and Process-related Design Change Causes

in the project makes the unpredictable circumstances during construction decrease. This could be explained by the fact that sharing information and making it available for everyone should help practitioners predicting the possible circumstances that can arise in construction projects, especially when the information comes from different sources and disciplines.

The ninth correlation found significant is a negative 0.302. It is assumed that an increase in the sharing and availability of information would decrease the lack of coordination and communication between the projects. Inherently, making information available is a way of enhancing communication between the different parties of the project. These should increase the coordination between the practitioners in the project, since by sharing the information constantly, the coordination of how to do so should help creating coordination in the team.

For the tenth significant correlation found, which is a negative 0.332 correlation, the reasoning is somewhat inherent. Since an increase in the sharing and availability of information within the project, there would be a decrease in the problems in the availability of information within the project.

The eleventh significant found correlation is between the sharing and availability of information and the existence of multiple and not aligned schedules in the project. Here a negative correlation of 0.441 was found. The direction of the

correlation is the assumption of an increase of the sharing and availability of information within the project, will make the existence of multiple and not aligned schedules decrease. Since the information is shared and made available for the whole team, we can talk about standardized information process. The standardization creates a simpler way of finding the information, decreasing the possibility of multiple schedules being active simultaneously and the misalignment of tasks within different schedules.

The last significance found correlation here is between the sharing and availability of information within the project and the overlapping of design and construction phases. Here a negative correlation of 0.187 was found. Although the availability of information could help an overlapping of design and construction phases existing, for this correlation no plausible reasoning could be thought of.

In conclusion, the correlation of the components extracted from the Principal Correlation Analysis has a negative correlation of 0.447. The direction of the correlation can be assumed to be increasing the cross functional and multi-disciplinary teams will decrease the process-related causes of design.

Deductions from the results of the analysis

After carrying out the analysis of the different correlation results, which can be seen summarized in Table 15, there are distinctive categories of types of relationships. Firstly, the positive correlations without directions, like C, D and H. Secondly, the positive correlations with the expected direction which means that the flexibility enablers affect the

			Correlation	Strength	Significance	Relationship	Direction
A.	Incremental Planning	Client-related	0.316	Medium	0.007	+	→
B.	Incremental Planning	Process-related	0.270	Weak	0.045	+	→
C.	Incremental Planning	Site-related	0.202	Weak	0.045	+	
D.	Continuous Locking	Client-related	0.395	Medium	0.000	+	
E.	Continuous Locking	Design-related	0.392	Medium	0.000	+	→
F.	Continuous Locking	Contractor-related	0.268	Weak	0.007	+	→
G.	Continuous Locking	Process-related	0.420	Medium	0.000	+	→
H.	Continuous Locking	External-related	0.287	Weak	0.004	+	
I.	Cross functional and multi-disciplinary teams	Design-related	0.344	Medium	0.001	-	→
J.	Cross functional and multi-disciplinary teams	Process-related	0.447	Medium	0.000	-	→

Table 15 - Correlation Analysis Summary

different categories of design change causes. These are A, B, E, F, and G. And thirdly, the ones that have the same direction as the latter ones but have a negative correlation, which are I and J. From now on, these categories will be called in already established order: “Undefined direction correlations”, “Negative Proactive Flexibility Recourses” and “Positive Proactive Flexibility Recourses”. These will be explained further in the next paragraph.

Undefined direction correlations: These correlations are between incremental planning and site-related design change causes, continuous locking, and client-related design change causes, and between continuous locking and external-related design change causes. These different correlations between the variables had a strong aspect in common which is that no logical reasoning could be thought of to determine the direction. This happened mainly because the factors which are contemplated in the design change causes did not had connections with the project management itself. This is necessary to mention since what is being studied is whether the applicability of flexibility recourses in the planning of projects may be a proactive measure to help manage the causes of design change in projects. Many of the causes of change within this examples occur before the planning of the project is made, since are the base from where to build up the project management plan. As well, many of these causes were independent of what can be planned for a project since external causes cannot be controlled by the project team. These are aspects as economic or political factors, or extreme weather conditions.

Negative Proactive Flexibility Recourses: These correlations had the opposite effect of what was expected to happen. Given that the use of flexibility recourses in a proactive way do not help manage causes of design change, but rather the opposite. Since the more the flexibility recourse is used the more that the causes of design change appear. These are mainly Incremental Planning and Continuous Locking, which as flexibility recourses their relationships with causes of design change does not explain how to control the causes of design change from appearing or managing them.

Positive Proactive Flexibility Recourses: These correlations are only two, and both involved with cross functional and multi-disciplinary teams. This flexibility recourse has two main correlations with the design change causes, being design-related and process-related. Between these there is a negative correlation, which means that they move in opposite directions. These relationships are the ones that actually had the expected effect on design change causes. When cross functional and multi-disciplinary teams increase the design change causes are reduced. Meaning that using this flexibility recourse as a way to control the appearance of causes of design change may be possible. These have logical reasoning behind their assumptions and interpretations which could be an indicator of being helpful to diminish these types of design change causes: design-related and process-related.

4.6 Flexibility

Within the survey, the last section of it included some optional open questions for the respondents to answer about flexibility. The response rate for these open questions was 60% over the total quantity of respondents of the survey. These questions were thought as a way to understand the mindset of the practitioners who formed part of the survey, and their perspective on flexibility in project management, planning of projects, and their own experience with it.

Analysis of open questions

The process of analysis of open questions was done analysing each response for each question and start recognising some key words and key concepts which embraces these responses. Following, response by response were analysed for each questions. The system was to count how many times did each concept appear in the responses and divide the final sum into the quantity of responses that question had, creating percentages. Each response could have more than just one concept within, that is why the total count does not give 100%.

Results of open questions

For the first question the answers were varied but a similarity in the thought process is seen when observing that “adapt to change” and “overcome challenges” where the two highest responses, can be seen in Figure 21. The interpretation of these, summed up to the “accept change” response rate, make us think that a major part of the respondents agrees that change will happen in projects and as a way of overcoming to these challenges there is a need to adaptation to the new situations. As well, there is an emphasis in which “teamwork”, “collaboration”, “trust”, and “clear communication”, become part or actions that add flexibility in the project management to adapt to these new situations. These four statements are very interrelated between them and how the management of the project is and the working environment.



Figure 21 - Survey Open Question 1

The second question focused on the planning of projects continues in the same line being a lot of responses “adjust to changes” and “regularly update planning”. It can be observed in Figure 22, that ways of being flexible in planning are named as having “contingency plans” put into place as well as “re-sequencing the plan” when it is needed as a way to adjust and adapt to possible changes. It is mentioned an aspect of how people work together by the factor of “collaboration with disciplines and team”, practitioners see that as a way to add flexibility into the planning, by bringing expertise from different people and different specialisations. It calls the attention that “constrained planning” which would be a more traditional approach has been the response of several as an opposite of flexibility.

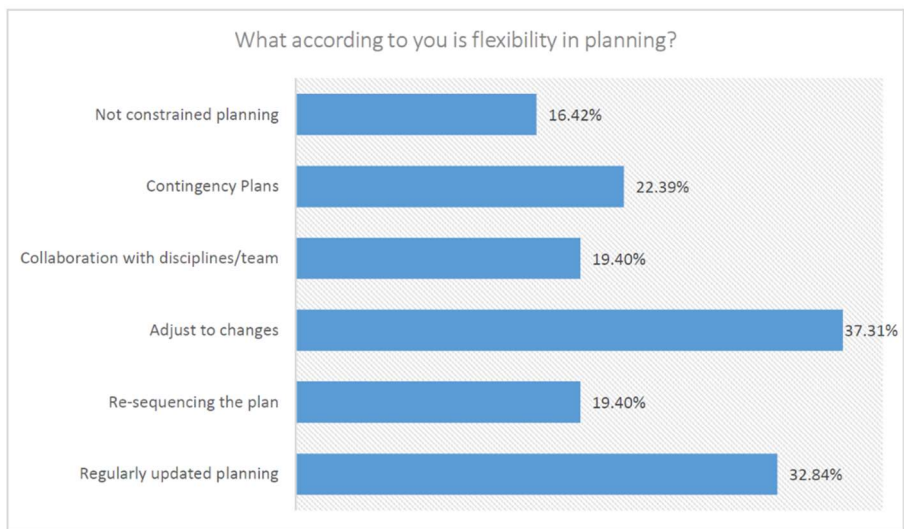


Figure 22 - Survey Open Question 2

For the third question on flexibility practices used, there is a substantial disparity between answers observed in Figure 23. The most used practices which respondents see as ways of adding flexibility are using the “Last Planner System” and “collaboration with trades, team and stakeholders”. Even a pretty large portion of the respondents have never used a practice which increases flexibility.

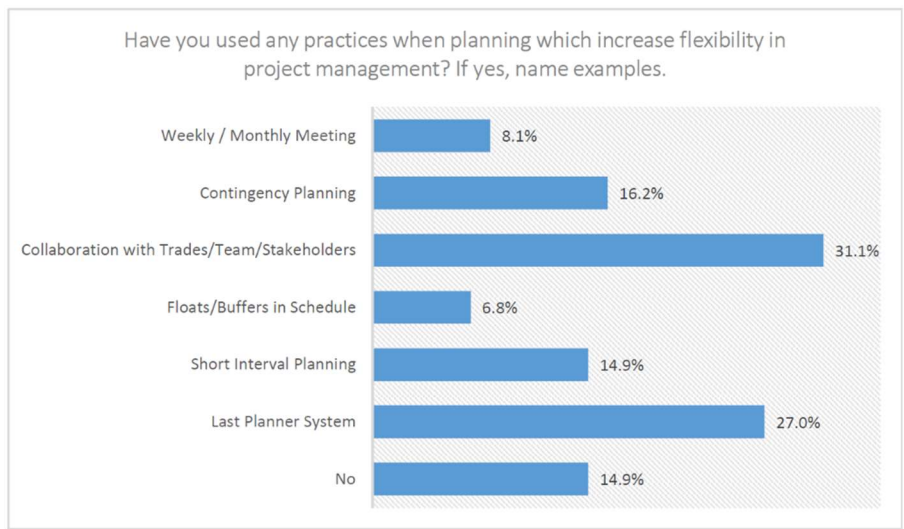


Figure 23 - Survey Open Question 3

Fourth question, which responses are seen in Figure 24, are aimed at understanding which benefits practitioners see from the use of flexible practices. Overall, the responses are quite positive, and flexibility is seen as something that can be an “efficient and effective approach” to projects earning “team building” skills in the process. It is also interpreted as “new opportunities” in the planning area and to explore different ways of doing things. It is also considered to be a quite useful tool to “improve relations with the client and stakeholders” in the project. Which gives an overall high beneficial perspective of using flexible practices, even though a number of people have never tried using them.

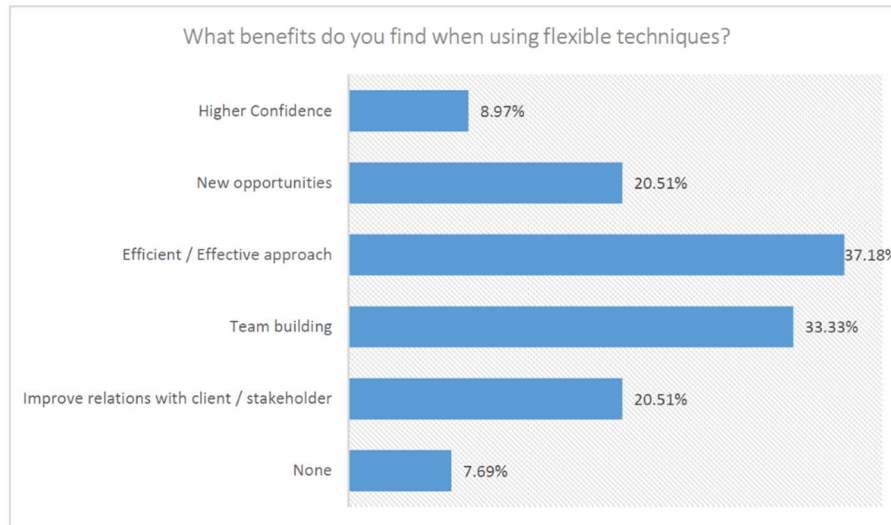


Figure 24 - Survey Open Question 4

Lastly, the fifth question which asks about the drawbacks of this flexible practices has a substantial quantity of respondents thinking that by using these practices they will have a “lack of control” over the project. As well, many of them believe there would not be enough engagement from the team into introducing these type of practices. They distrust that projects will not be slowed down by these practices and they have less confidence in introducing them in their daily work. Some of them blame it on communication problems, but others believe that an increase in resources

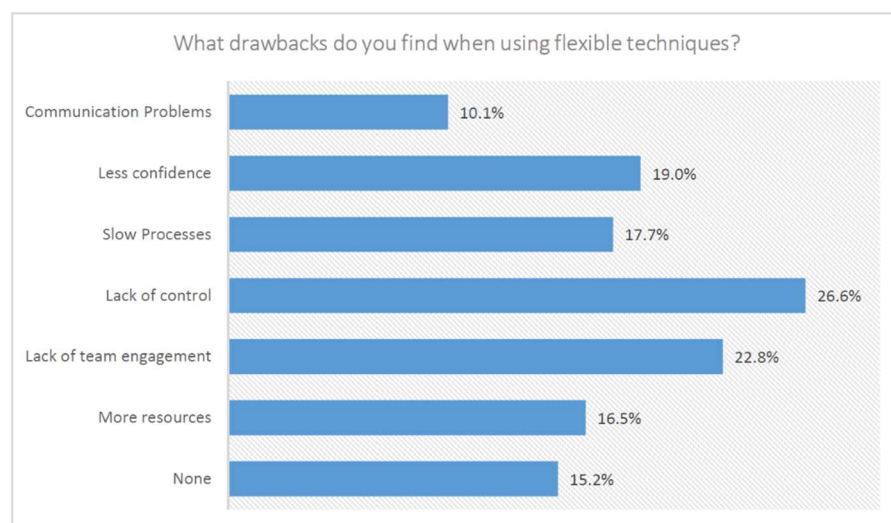


Figure 25 - Survey Open Question 5

(economic, time, human, etc.) will be needed if flexibility is added in the planning of construction projects. Although there is more than 15% of respondents who believe there are no drawbacks into using flexible practices if used correctly.

Consequently, it can be said that practitioners at DPR have an awareness on what flexibility intends to do at a project management level, as well as in a planning level. Even though not everyone is aware of this term, some others do understand what flexibility could look like in the management of projects, when compared to more traditional approaches. The benefits of using these practices are mentioned by the respondents and are mentioned to help with becoming more efficient and effective in the approach, have a better relationship with the client, improve team building and open doors for new opportunities in the field. However, there is a portion of the respondents who have never used these practices or approaches into their daily planning of projects or management of projects. And the ones that do, tend to use mostly two practices which are increase collaboration between the different parties working in the project and using the last planner system. And these practices are not being used, even when the same respondents find less drawbacks than benefits. Overall, it can be said that practitioners like the concept of using a flexible approach into projects, they seem to have the knowledge of some practices and the possible benefits and drawbacks from it, but still decide not to carry out their management style in this way. But using more traditional project management practices There is very little real use of these practices.

4.7 Conclusions

In this chapter the analysis of the data gathered by means of surveys was carried out. The analysis of the data was done by correlation analysis for complexity, design change causes and flexibility statements. Factor analysis and principal component analysis as a form of reduction of the big number of variables. And pattern detection and its following interpretation for the open questions on flexibility. These methods of analysis have quantitative and qualitative approaches. In order to sum things up, a synthesis of the different parts will be presented in this section.

The analysis of perceived complexity by practitioners was focused into how complexity affected the design change causes, for this it is considered that complexity is an independent variable and change causes will be dependent on complexity. Complexity will as well be independent from the flexibility recourses since the complexity of the project is a characteristic of the project and does not depend on the flexibility recourses used in the project, and vice versa. Three main correlations were found between the complexity variables and design change causes. All of these were positive correlations, meaning that an increase in complexity has an effect on the design change causes increasing it by a ratio. The importance of this analysis relies in the fact that complexity does have an effect on design change causes, the more complexity the more design change causes that will appear in a project. Meaning that more flexibility will be needed to manage these changes. There is an indirect relationship between flexibility and complexity, given that complexity in projects urges the management to be more flexible and therefore more changes arise in the project.

In the second part of the analysis, the correlation between the flexibility recourses and the design change causes was established. From these analysis ten main correlation were extracted. These relationships were ordered in three different categories: undefined direction correlations, negative proactive flexibility recourses and positive proactive flexibility recourses. In the first category, the direction of the relationship between these variables could not be defined since logical assumptions could not be made. These means that even though a relationship was established, which is the variable that affects the other one could not be determined, neither its causality. These was mostly related to the fact that the design change causes in these correlations do not have a clear involvement with aspects of Project Management. The second category is formed by positive correlations where flexibility recourses have an effect on design change causes. Given that the correlations are positive, the more flexible recourses the more design change causes that will appear in the project, the opposite that was hypothesized. Third and last category, are those relationships between variables that will actually benefit the projects. Meaning that the more use of these flexible recourses the less causes of design change that will appear in projects, having a positive effect on the proactive use of flexibility recourses as a way to manage the design change causes.

Lastly, after analysing open question answers it can be said that practitioners do have awareness about flexibility in project management, and in project planning. The majority of the responses for this two questions support what has been described and defined in previous research. There is an awareness on the benefits that flexibility might bring into construction projects, and practitioners also mention drawbacks of its implementation in projects, but still there is a substantial quantity that has not tried to implement any flexibility practice into their projects. And a major part of the ones that did have used the Last Planner System and Collaboration with different parties within the project. These two practices are big part of Lean Construction which is currently being used as a basis in the company.

5. PROPOSED SUGGESTIONS

In this chapter the conclusions of the research will be analysed and transformed into proposed suggestions of how to use this new information. Thus, the flexibility recourses and their effect on design change causes will be discussed, understanding why these effects occur and how can they be taken into practice. For this the suggestions will be separated into three categories: flexibility recourses with positive effects on design change causes, flexibility recourses with negative effects on design change causes, and flexibility recourses with undefined causation on design change causes. Furthermore, the development of a roadmap for the practical implementation of the proposed suggestions is presented.

5.1 Flexibility recourses with positive effects on Design Change Causes

After carrying out the analysis established in the previous chapter there were two main relationships that were defined as having beneficial effects for managing the design change causes in construction projects. Both of these relationships were affected by the flexibility recourse of cross functional and multi-disciplinary teams, see Table 16. When using this recourse, a minimizing effect on design-related and process-related design change causes occurs. This is useful to minimize the design change causes that appear in projects and help managing them on projects. The reasoning behind it lies in the two statements used to describe this flexibility recourse during the analysis. Firstly, the statement of: “there is an involvement of all parties and disciplines in the project working together as a team”. And secondly, “the information is share and available for all the different parties in the project”.

	Flexibility Recourse	Design Change Causes	Correlation	Strength	Significance	Relationship	Direction
I.	Cross functional and multi-disciplinary teams	Design-related	0.344	Medium	0.001	-	→
J.	Cross functional and multi-disciplinary teams	Process-related	0.447	Medium	0.000	-	→

Table 16 - Flexibility Recourses with positive effects on Design Change Causes

This recourse becomes useful for managing design-related and process-related change causes. Within design-related change causes the following aspects are considered: time constraints, modification to design, design errors and omissions, outdated design, inadequate information provided to designer, designer non-involvement during construction phase, discrepancies between contract documents, lack of awareness of governmental or municipal regulations, and incomplete drawings. Furthermore, within process-related change causes aspects such as: poor project organizational structure, unpredictable circumstances during construction, lack of coordination and communication, information problems,

fragmented schedules, and overlapping design and construction phases. Having this into account different suggestions will be created based in these.

The use of this recourse to involve everyone involved in the project may be more useful when used from the start of the project, creating a project team which has a strong cohesion and gets everyone involved in the project from the beginning. This is claimed by Hansen et al. (2020) in its research as one of the recommended mitigations for changes arising in construction projects, and emphasizes the necessity of it within the front-end planning phase. For implementing this, a work culture should be established where project engineers, design team, planners and every trade becomes personally acquainted and are used to working together as a team. Activities which promote team building should be prioritized by the organization, so as to achieve this level of teamwork. Additionally, the culture within the company should encourage practitioners to work on creating good relationship with subcontracts, providers, and trades, to maintain the cohesion and the teamwork feeling in the project. Likewise, it is mentioned in the research by Keane et al. (2010) where it is argued that the improvement in the coordination between parties involved is one of the general mitigation strategies to be used in construction projects.

Scholars hold that one of the alleviation on the effects of changes in projects sharing information between parties involved in it is essential (Hansen et al., 2020). Additionally, others mention a common database system as a possible solution (Alnuaimi et al., 2010). This would not only help establishing better links between the team members, but also would help to provide availability of information to everyone working on the project, an open communication, and an orderly way of storing selected information. The common database system is a way to standardize the information within the project, being this information of common knowledge to every party and of easy access to it. The tool to reach this can be selected by the company, and there are many options in the market that achieve this but is of utmost importance that awareness is raised about the tool and its functionalities to everyone. This diminishes fragmentation in information and communication between the different roles within the project. Which has been established as one of the change cause factors in construction projects. A possible way of making the information available for everyone on the team is to have an ordered common filing of all the documents used in the project. As well, to make communication of advances and keep everyone in line with what is happening in the project, a weekly report could be sent to all different team members. This report could inform of the objectives reached during the week, the objectives for next week, naming the different subcontracts, trades, and team members responsible for it. Also, the risks and possible clashes between trades, not only physically on site but on their tasks should be adverted. An overview of the status of the planning could be included as a way to let everybody that forms part of the project be updated on how things are going within the project. These could avoid misunderstandings, lack of shared information between trades, and steer clear of possible delays or clashes between trades because of any adjustment to the planning.

Overall, there should be a clear motivation from the company’s management to promote the teamwork in projects and the incorporation of different disciplines within the project team. As well as incentives on creating a proper communication and information exchange between parties working in the project.

5.2 Flexibility recourses with negative effects on Design Change Causes

	Flexibility Recourse	Design Change Causes	Correlation	Strength	Significance	Relationship	Direction
A.	Incremental Planning	Client-related	0.316	Medium	0.000	+	→
B.	Incremental Planning	Process-related	0.270	Weak	0.045	+	→
E.	Continuous Locking	Design-related	0.392	Medium	0.000	+	→
F.	Continuous Locking	Contractor-related	0.268	Weak	0.007	+	→
G.	Continuous Locking	Process-related	0.420	Medium	0.000	+	→

Table 17 - Flexibility Recourses with negative effects on Design Change Causes

The analysis in the previous chapter gives an insight into how some of the flexibility recourses had the opposite effect than the one expected. These flexibility recourses as continuous-locking and incremental planning had a negative effect on managing design change causes in projects, see Table 17. Meaning that these two recourses increase the design change causes appearance. Incremental planning makes client-related and process-related design change causes increase. Meaning that aspects like poor project organizational structure, unpredictable circumstances during construction, lack of coordination and communication, information problems, fragmented schedules, and overlapping design and construction phases, increase when incremental planning is used. As well as, aspects related to the client such as changes in requirements and scope changes, use of new technology, omissions in the scope, inappropriate use of type of contract, unclearness in the brief, time constrains, modifications to the design, design errors and omissions, inadequate information provided to the designer, non-involvement of design during construction, discrepancies between documents, lack of awareness of regulations and requirements, and incomplete drawings will appear more often if incremental planning is used. And continuous locking affects design-related, contractor-related, and process-related design change causes increase. From these, design-related and process-related have been already mentioned but within contractor-related aspects as requests to use available materials or alternative construction methods, incomplete plans and specifications, requests on improving buildability and insufficient working drawings details will increase its appearance in

the project. Even though these findings show that some flexibility recourses as the ones mentioned above have the effect to evoke design change causes in projects, it does not mean that this flexibility recourses could be used in other ways.

In previous chapters it has already been mentioned the studies of several scholars which highlight the fact that the flexible paradigm in projects can have undesirable effects and for it to be successfully implemented there should be mitigated by the balance between paradigms. This is mentioned by Pollack (2007) who argues that the use of soft paradigm and hard paradigm is necessary to achieve the best outcome of a project in today's times. Thus, it is needed to apply in practice not only problem-solving tools as traditional approach does but adding what he calls problem structuring which is based on a more flexible approach which is open to changes. It is implicit in the hard paradigm the assumption of detail planning allows more control and, therefore, is better. However, empirical evidence suggests that this is not always the best case for projects since unpredictable change will appear (Pollack, 2007). Likewise, in the research by Joana Geraldi (2008) it is presented the fact that projects demand both paradigms, the mechanic (traditional approach) and the organic (flexible approach) one. This is described of being a necessity of the complexity that nowadays projects phase and the highly dynamic environment presented (Joana Geraldi, 2008).

Furthermore, this is mentioned in the prepare and commit paradigm (flexible approach) versus predict and control paradigm (traditional approach) by Koppenjan et al. (2011), where it is argued that these two approaches need to be combined and balanced to successfully manage a project. Koppenjan et al. (2011) develop a framework that sums up the differences between these two approaches and claim that neither approach can fully manage today's complex projects, and in line with Joana Geraldi (2008) they expect that these approaches are combined in practice. Thus, this will be one of the proposed suggestions of this research to balance between traditional and a more flexible approach for project management. Based on Koppenjan et al. (2011) whom describe the flexible paradigm as "prepare and commit", in this approach overcoming changes and uncertainty is constant and is shared between the different parties working in the project. The inevitable changes in projects and dynamics lead to the use of a functionally specified terms of reference for the project and a broad task definition as close cooperation between parties is needed. So as a way to control the negative effects of incremental planning, narrowing the task definition would help with managing design changes. This alludes to the already stated possibility which contemplates the use of flexibility as a way to manage design changes after they appear in projects instead of using it to stop changes from arising.

Furthermore, the open question analysis, in which the opinion of practitioners about different aspects of flexibility is collected gives a comprehensive understanding of the mentality behind these people. It was adverted that practitioners are quite aware of what being flexible in project management entails, and likewise about flexibility in planning. Although, when asked about their experience in using flexible practices a substantial number of respondents had never used any kind of flexible practices. This could be assumed in different directions, such as the company not supporting this type of practices making respondents work within the company's common practices, or respondents not being aware about flexible practices even when using them implicitly. For this, based on the study of Surve (2020) it is suggested to create

awareness about these flexibility recourses and practices, provide training workshops on flexible practices to practitioners and management to be aware and informed of these practices as a solution to the lack of trust and understanding. As well, the company support on practitioners when wanting to innovate in their project management skills and practices. It is recommended that for incentivising people to search for more efficient ways to plan and manage projects there is a constant sharing of information of projects which implemented these flexibility recourses and their lessons learned from it (Surve, 2020).

Another aspect that came to light with the open questions was the wide variety of benefits found by practitioners about implementing flexible practices compared to the negative aspects of it. Whether if practitioners know by own experience about the benefits and fallouts of flexibility recourses it is not known but can be assumed to be the ideas that a brand majority of people within the management of construction projects may have about new styles of management. The construction industry tends to be more traditional than other industries and is not willing to change work methodologies very easily. These translate into two different suggestions based on the work by Surve (2020), for overcoming with this type of mindset. Firstly, highlighting the positive aspects of applying these flexibility recourses, and concentrating the efforts on its advantages. Secondly, trials of flexibility recourses use in projects could be useful not only to raise awareness of them but to gain acceptance within the workers of the company.

5.3 Flexibility recourses with undefined causation on Design Change Causes

	Flexibility Recourse	Design Change Causes	Correlation	Strength	Significance	Relationship	Direction
C.	Incremental Planning	Site-related	0.202	Weak	0.045	+	
D.	Continuous Locking	Client-related	0.395	Medium	0.000	+	
H.	Continuous Locking	External-related	0.287	Weak	0.004	+	

Table 18 - Flexibility recourses with undefined causation on Design Change Causes

This section is categorized for those flexibility enablers which a logical reasoning behind the relationship with design change causes was not found, see Table 18. These relationships have a clear negative effect on design change causes. The majority of design change causes in these relationships are external causes that could not be controlled by project management, like extreme weather conditions which come out of the average weather conditions of the project site. And design change causes that timewise occur before the planning is done and little have to do with project management, nor even can be controlled by it. These relationships are suggested to be treated as risks if they are external to the possibilities of control by the management of the project. Or simply accepted as a possibility, since the fact that a

correlation between these two factors was found in the analysis does not mean that there is a direct causality for it to happen.

5.4 Development of Roadmap

In order to implement the suggestions proposed in the above section, a roadmap will be developed. This roadmap will act as a guide for implementing this suggestions. This guide is aimed not only at the company, but practice in general. The roadmap can be observed below in Figure 26. The roadmap is divided in two clear phases for the implementation and phase 1 should have been completed to be able to start implementing the phase 2. The idea behind this guide is to simplify the implementation of the suggestions in a time order which will benefit the practice and become easier for practitioners to transition into these new work methodologies.

FIRST PHASE

The first phase can be considered the easiest one to apply, since practitioners already trust in these methods and suggestions. The acceptance of these suggestions by practitioners will simplify its implementation in practice without having pressure against it, since the company has been already using some of these as part as their main work methodology. Because of this, the suggestions of the first phase will probably have a rapid effect on projects.

Suggestion 1: Involvement of all parties since project starts

By involving everyone since the beginning of the project gives the advantage to have multiple disciplines working together in a way that can share knowledge on their areas and a better planning can be made based on their expertise. These different specializations being involved mean being able to catch possible errors or omissions before the construction starts giving an advantage of eliminating the need for changes once the project is on the go. The specializations can be practitioners from the construction company, as well as the engineers of different trades involved in the project, or any third party involved in the project in some way.

Suggestion 2: Implementing a work culture in the company that prioritizes team-working

If the company is behind the team-working commitment, prioritizing and encouraging practitioners into using this work methodology it eases into using this type of approach. For these practices to be implemented fully the company has to be behind them giving the impulse for them to work. This can be translated into weekly meetings with the whole team to have updates in the situation of every task and planning.

Suggestion 3: Promotion of team-building activities

Team-building practices are suggested to be promoted and implemented as a normal condition within the company. These will encourage practitioners to work better in teams and be more willing to become part of it. These soft skills are necessary for generating the collaboration that is sought. As well, by establishing good relationships in the work team communication and exchange of information will become more efficient.

Suggestion 4: Encourage practitioners to establish good relations with third parties in the project team

The need for creating good relationships between the parties involved in the project go beyond the direct workers of the company, including all the third parties, subcontracts and trades being part of the project. Good relations with these parties will create a better and more effective way of working, easier collaboration and exchange of information, and project success.

Suggestion 5: Prioritize the availability of information for all parties

Making the availability of information a priority in the company's work methodology is crucial when wanting to implement a more flexible approach into the planning and management of projects. This prioritization is needed to generate the change from how practitioners have been working until now into the new modality. It needs to be established that the information must be available for all parties involved in the project and highlighted to workers to follow this work methodology. If workers do not appropriate this work methodology the successful implementation of flexibility recourses will not be possible.

Suggestion 6: Simplifying access and availability of information

In today's projects the complexity of projects is substantial increasing the need to have a bigger number of subcontracts and outsourced recourses, these create a fragmentation in the information handled by every party within the project. As a solution for this problem, it is suggested to use a simple system in which information is stored and uploaded in a simple way and the access to it is simple for every party working in the project. This way, the information is accessible for everyone creating simpler, faster, and more efficient exchange of knowledge of every task on the project.

Suggestion 7: Standardization of organised storing information

In an attempt to simplify the availability of the information for everyone in the team, a clear and standardized way of organising the information would be highly beneficial. By having a standardized format for every project practitioners have an efficient way of organising the project and themselves, without creating problems for its availability for the rest of the parties involved. As well, standardization of the information exchange helps control the project in a more traditional approach, making the change into implementing flexibility recourses an easier step for everyone.

Suggestion 8: Weekly reports with projects status sent to every party involved in project

The practice of sending weekly reports in a standardized fashion can help communicate weekly advances in the projects to everyone involved in it somehow. This can give introspective information to the project team as well as trades working on the project, like possible future risks based on past events and following the plan in a weekly basis being in the loop of how the planning is running or how the planning was altered based on that week's work. These also helps practitioners to do an evaluation of the current plan and the possible necessity of re synchronizing it.

SECOND PHASE

The second phase is meant to be used as a way to gain acceptance of these new management styles into an industry which tends to be very traditional and not very accepting of changes as established by Surve (2020). By the use of a combination of traditional and flexibility recourses, making an emphasis on traditional project management practices, it is expected that practitioners may be more willing to add these new techniques into their daily work methodology. Especially, once the changes have already arisen since it can help control these changes, not evoke more design change causes. Additionally, this phase is needed to raise awareness of what flexibility practices are and make an emphasis into highlighting positive aspects of its usage and lessons learned from projects which implement it.

Suggestion 9: Balance the use of a broad task definition with a narrow one, for best control of design changes

The aim of this suggestion is to follow what was established before based on the work of Koppenjan et al. (2011) in the only way to manage a successful project is to balance the two management approaches. The balance should be done in the management approach since the task definition will create the structure from where to base the project. By narrowing the task definition, there is an increase in the control of the project. By having a better control, the different changes that arise during the project will be easier to manage its impact.

Suggestion 10: Use traditional methods in planning to control the appearance of design change causes

As suggestion 9 argues there is a need of balance between control and flexibility in project management. Traditional approach to management tends to seek for control, and that is what is needed to counter the effects that flexibility recourses have on design change causes. By using traditional methods in planning and not only flexible approach, a control over the appearance of changes can be achieved. These can be done by limiting the use of these flexibility recourses of continuous locking and incremental planning. A traditional approach can be used as the base of the planning and flexibility recourses used when needed, such as adaptation to possible changes arising in projects.

Suggestion 11: Sharing information on projects which implemented flexibility recourses and their lessons learned

The exchange of information about projects helps incentivize the correct use of strategies and flexible recourses in projects. As a way to improve the practices used it is imperative that the lessons learned in individual projects is divulged in the form of lessons learned. This gives the opportunity to improve at a greater scale and faster pace that without knowledge being shared throughout the company.

Suggestion 12: Flexible recourses used as measures for managing design changes, not design change causes

Flexible recourses have been proved to increase the amount of design change causes that arise in projects. However, flexibility recourses could be used as a tool for managing design changes once they appear in projects. Once the change has appeared and stated in the project it should be analysed deeply its impact and follow the traditional approach. Although, continuous locking and incremental planning can be used while decision about change are being made. This helps establishing decisions or aspects on how to manage the change as the information needed becomes available. Leaving the possibility for being flexible in aspects which may be decided at a later stage for lack of information.

Suggestion 13: Company support by generating trials of flexibility use on projects to gain acceptance of these practices

The company has to be on board to be able to implement these suggestions. Such is that without the encouragement from the company and its incentive it is not possible to create the culture for practitioners feel confident enough to innovate in management and planning practices. This can be made stronger by generating trials of these practices in projects to gain acceptance in its use by practitioners.

Suggestion 14: Provide training workshops on continuous locking and Last planner System

One of the things that were noticed in the open questions was the lack of use of flexible practices even though practitioners argue to be aware of them and their benefits. Especially continuous locking and last planner system. It is considered that if workshops to train practitioners on these are implemented, practitioners will have the knowledge to apply these practices into their management approach. As well, training will give practitioners more information on how to apply this approach without losing control of the project which is the main insecurity and pitfall that practitioners notice from flexible practices.

5.5 Conclusion

In this chapter the development of the proposed roadmap has been explained. It creates an orderly application of the different suggestions, for its effective implementation. Every proposed suggestions listed in the different phases of the roadmap for the implementation of the flexibility recourses have been explained. As well, the implementation process

and reasoning has been discussed. With a successful implementation of suggestions, it should be easier to see an incorporation of flexibility practices within the projects in the planning and management areas. The proposed roadmap as well as the proposed suggestions will be further validated for its applicability by experts in the next chapter.

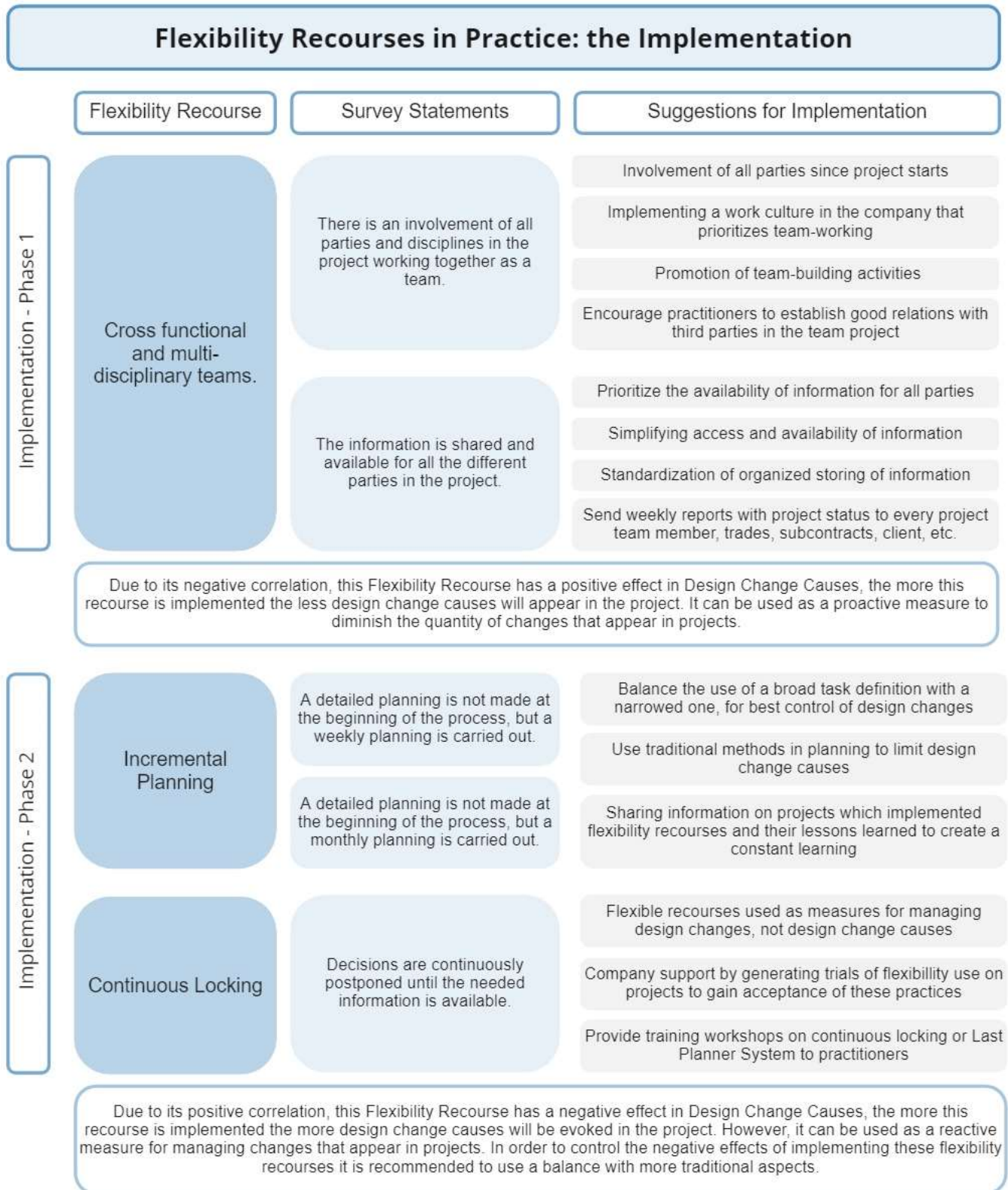


Figure 26 - Flexibility Recourses Implementation Roadmap

6. RESEARCH VALIDATION

In this chapter, the roadmap for implementation of flexibility recourses in practice and the proposed suggestions of last chapter are validated through experts. Primarily, the first section will explain the approach for conducting the validation by experts. Subsequently, the applicability of the proposed suggestions and the implementation of the roadmap developed will be discussed.

6.1 Set-up Expert Session

The goal of the expert validation is to validate the roadmap developed for the implementation of the suggestions and the suggestions per se. To accomplish the validation an expert session will be carried out. The participants of this expert session were DPR Construction's employees, which are experts in the planning area, information on participants can be found in Figure 27. The expert session was carried out online using Microsoft Teams and Microsoft Forms, due to the geographical location of the different participants.

	Name and Surname	What is your current role in company?	How many years of experience do you have in total?	How many years of experience in this area of work?
Participant 1	Matt Stevens	PSPP Lead Europe	26	20
Participant 2	Lael Blum	Operations Lead	16	16
Participant 3	Matthew Wahl	PSPP Regional Lead BENELUX	12	6
Participant 4	Joss Pettitt	Senior Planning Manager	22	17

Figure 27 - Participants Expert Session

The expert session counted with three main parts. Firstly, a presentation on the research thesis and the suggestions as its output was carried out, as a way to introduce the participants into the subject and what is going to be discussed later. Secondly, a brief questionnaire is asked to be filled by every participant. This questionnaire aim is to gather individual opinions on the different suggestions and phases of the roadmap, the whole questionnaire can be found in Appendix I. After the participants completed the survey, the suggestions were discussed. Lastly, the main roadmap and its applicability were discussed. The duration of the complete session was of 2 hours. The protocol for the expert session can be found in Appendix H.

6.2 Discussion on Validation proposed suggestions

In the first section of the expert session, a discussion of the proposed suggestions is done. The suggestions are assessed by each practitioner individually by the use of a survey. The survey was introduced to the participants during the session, and they accessed it online, they had 15 minutes to fill it in. The experts were asked if they agreed with the proposed suggestions in its suitability and applicability of them as a way to increment the use of flexibility recourses in the planning of projects. The survey was divided in the suggestions per phase and will be analysed using the same methodology. The assessment was made using a Likert scale from totally disagree (1) to totally agree (5), followed by three open questions:

- Do you have any practical objections towards any of these suggestions?
- Do you believe there is any added value from these suggestions?
- Any additional suggestion to add or complement an existent suggestion?

The following sections will show the results of the expert session per phase of implementation, based on survey answers and posterior discussion.

VALIDATION OF SUGGESTIONS FOR IMPLEMENTATION PHASE 1

In general, the experts agree that these suggestions are suitable and applicable for implementing flexibility recourses in construction projects. One practitioner mentioned that these suggestions are all valuable for the growth of DPR Construction as a company. Another one added that higher levels of information transparency and collaboration are always positive, making the suggestions valuable and applicable. Also, the same noted that the team working methodology proposed aligns with the company culture completely. A third one argued that these suggestions have added value in the fact that they centre around a common-sense approach which can be implemented across projects easily. Lastly, the fourth expert commented that some standardization in the right areas can make everyone's daily tasks easier. Although, during the discussion it was mentioned that DPR's position on standardization is not a hard one, only minimum information is asked to be standard, and it is not negotiable. One of the experts mentioned: "the company tends to be flexible by nature, an evaluation of how flexible we should be, may be good for understanding where the limits are".

However, the challenge found for the implementation of these suggestions is around the education of team members which will need an investment of time for succeeding. Moreover, another expert mentions that sometimes at the beginning of preparations for the project divisions of information are made and make it difficult for some parties within the project to know what information is for them to look at, especially when all information is shared. This should be made clear since the beginning and can be done by a standardization of how information is filed and order, as well as giving the practitioners the tools to understand exactly where their responsibilities fall into.



Figure 28 - Suggestions Phase 1 Survey

Overall, it was stated that “standardizing or agreeing early on the different categories and distribution of information with parties may help in facilitating wider buy-in to help manage change”. In addition, one of the experts mentioned that normally when thinking in teams they just thought within the construction company and agreed that by broadening this and introducing in the team consistency of stakeholders and having in the table the “people that actually has decision power” could create a great improvement. What’s more, it was added that “being part from the beginning of the project into what is the end product, being part of the decision making and working closely to the design team and stakeholders would be beneficial” because this permits the construction team to “have the knowledge and opportunity to cheap in during the process”. Also, these suggestions and adding flexibility recourses in projects are considered to be suitable for facilitating manage changes in projects.

VALIDATION OF SUGGESTIONS FOR IMPLEMENTATION PHASE 2

For the suggestions of phase two there are two clear distinctions between them, having a great duality on the aspects they influence. The experts agree with the majority of suggestions being suitable for managing design changes and their validity for its implementation.

While discussing these suggestions it was mentioned that normally the majority of changes come from design, and how hard tracking them tend to be when the lumps of new blueprints from design team flows into the project. It was stated that “normally as a construction company we are already working while the design continues changing”. An expert also brought up the following statement: “we should not be having such a passive attitude towards changes but thinking how flexible is flexible enough”. It was noticed how the flexibility recourses can actually help in the management of design

changes. During the discussion it was raised the question “What is the cost of flexibility?” while discussing that the company’s culture is quite flexible as one of their core values, and normally an optimistic view is the one commanding projects, where flexibility is a must but with it comes taking risks. But these risks can get out of control easily, and “there should have limits or boundaries to somehow control it”. Suggesting a balance between a traditional approach and a flexible approach was taken as a possible way of creating these needed boundaries for the use of flexibility.

Furthermore, the suggestions on breaking the stigma were substantially mentioned as a good measure. One of the experts comment the following “I really like this approach to raising awareness and in turn the profile of flexible recourse’s”.

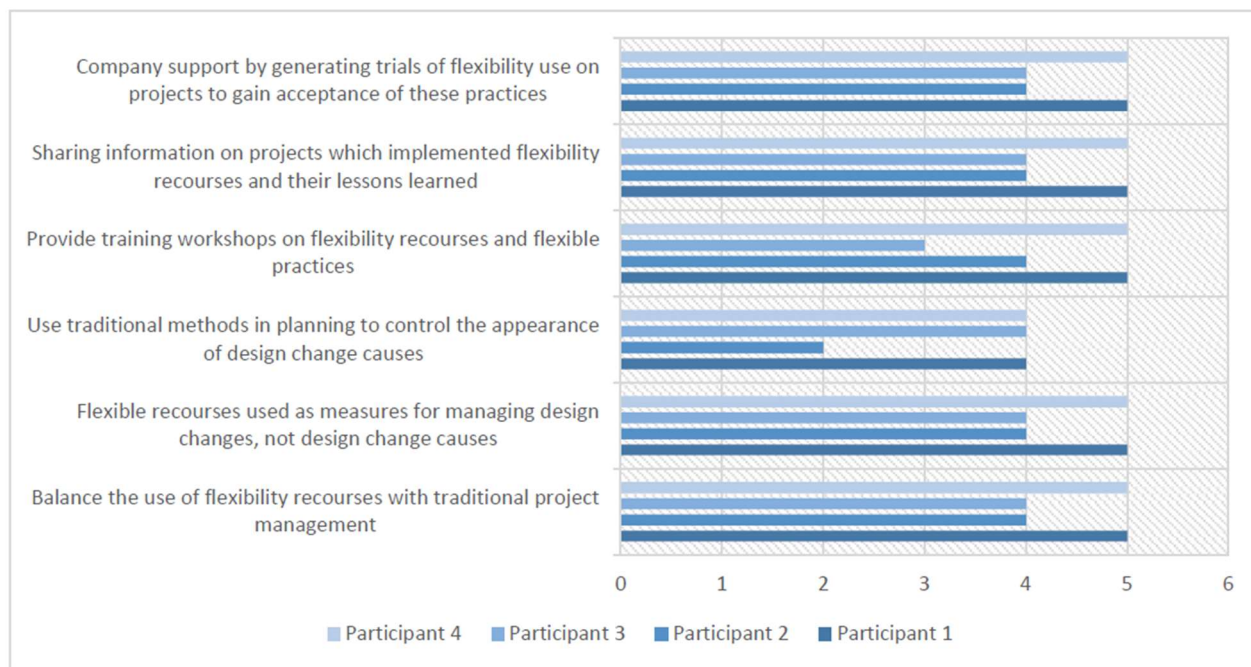


Figure 29 - Suggestions Phase 2 Survey

Another of the experts agrees with the added value of these suggestions and thinks that by raising awareness and training practitioners on understanding and identifying flexibility, will end up in having a better understanding of the flexibility it is now employed in the company. This being a great tool, since it helps understand the inherent work methods use and be able to improve them in a more efficient way with the acquired knowledge. In addition, a third expert mentioned that these training proposed could be more efficient if teams are trained together. Since that way they can recognize and implement what was learnt in the workshops together in the project they are working on. An important aspect mentioned as an addition to these suggestions was the consideration of how “lessons learn” are treated, since the experience of the company is the following “Lessons Learned sessions are delivered and filed away as soon as the session is finished and not revisited”. However, it is clear that the application of these will need a design that tracks the output of these sessions to make them more effective, but this will not be assessed in this research since it is out of the scope for the research objective.

Overall, practitioners agreed with the suggestions proposed in this second phase of the implementation roadmap. As well, it was mentioned that “these suggestions follow a Plan, Do, Check, Act cycle of improvement” which comprises a substantial validation for its implementation in this or any other company. The four experts agree that the suggestions for the second phase and its reasoning behind it suitable for its implementation and objectives.

6.3 Discussion on validation roadmap and implementation phases

In the second section of the expert session open questions were asked and discussed between the experts. The questions were focused on applicability, clarity, and recommendations on improving the developed roadmap. These questions will confirm the validity of this roadmap in practice. The open questions were the following:

Question 1: Do you think the proposed roadmap is valid and applicable in the company?

The experts stated that the developed roadmap is valid and applicable in construction projects and in DPR Construction. However, it was agreed that the proposed roadmap for implementation of flexibility recourses is not only useful for DPR Construction but in general any company would be benefited by it. As well, its use can be done not only for the planning, but every phase of the project would be improved by the use of this implementation guide. One respondent highlighted that by applying this roadmap an improvement in how teams work would be clearly achieved, generating a multi-disciplinary team throughout the horizontal organization of the project. Additionally, it would help create a project planning that is “better at reacting to changes”, being prepared for changes appearing and having the tools to manage them in a more efficient way. It was raised to attention that in the roadmap itself there is not specified exactly what each suggestion entails. This needs to be accompanied by the information in Chapter 5.

Question 2: Which phases/suggestions are not clear from the implementation roadmap?

The practitioners agreed that the implementation roadmap was straight forward and easy to understand, and the different phases were established in a coherent order. The only aspects raised by the experts as not being completely understood were how exactly traditional practice can be used to control flexibility recourses negative effects in projects and which type of incentives are the ones mentioned. The how traditional practice can help control that the design change causes are diminished could be explained deeper with the explanation of the suggestions. However, the use of this traditional approach is based on the balance between traditional and flexible but leaves place for each practitioner to be implementing it to follow these abstract concepts as it sees fit. There is not only one way of applying them since they are influenced by several factors, but each practitioner can diminish or increment those values depending on what is needed in the specific project. About the incentives, the experts were unsure which type of incentives since their understanding of that word had an economical connotation. It was established that it would be changed to a word which did not evoke the connotation of money, such as encourage.

Question 3: What should be changed or restructured from the proposed implementation to make it more applicable in DPR?

Overall, the experts are confident that the proposed roadmap is clear and is applicable for construction projects in this or other companies. Moreover, there is not a willing to change the implementation guide itself but do questions some aspects of implementing these suggestions in practice. One of the experts mentioned that in suggestion 10: “Sharing information on projects which implemented flexibility recourses and their lessons learned” the mentioning of lessons learned is something that even though it is already in use in the company the effectiveness has not been corroborated by them. In every project it is done a lessons learned reflective exercise but there is a tendency of leaving this information filed somewhere and not being used in other projects. Even though the experts believe there is a lot to make out of these lessons learned, it is not known how to implement them in a way to make them valuable. They theorize that the learning process for different person is different, and this should be considered when generating workshops or exercises of lessons learned.

Another expert mentioned that the continuance of teams may be important to be able to learn from practice. When teams are separated, they do not tend to work at the same level, and only by aligning teams to continue working together may help. The successfulness of the project has its impact over the lessons learned exercise, since the mood at the end of the project changes between a successful or a not successful project. When the project is successful people are more willing to cooperate and to create reflective thinking of how things could have been improved and optimizations done. However, when the project is not considered a success but quite the opposite, it is difficult for people to reflect upon what happened and creates optimizations for what happened. These two aspects are two things to have into consideration for the implementation of these suggestions, and these arguments have been acknowledged in this research. Although, the framework will not be restructured under these comments, leaving to the practitioners the responsibility of deciding how they develop the reflections upon the project, the lessons learn approach and its use. These go out of scope for the research objective of this research thesis and will not be included but can be done as a future step.

Question 4: Do you think the current working culture of DPR Construction is suitable for implementing this roadmap?

All experts agree on the fact that the culture of DPR Construction has as core values plenty of the suggestions proposed in the roadmap. Encouragement of their workers is done on a daily basis in different ways throughout the company, and “this is who we are, and do it well” commented one of the experts. They recognize the importance of implementing these suggestions and consider that the company recognizes the value of this type of working. So, they do think that the culture within DPR Construction is suitable for implementing this roadmap.

Question 5: The suggestions provided for the implementation are not new or unknown in practice. Do you think they are being used among practitioners in DPR? If yes, how? If not, why do you suppose it is?

The experts were in accordance with the fact that a lot of these suggestions are already being used in the company. Even though they are being used to different degrees throughout the company depending on different factors like: the experience of the project manager in charge of the project, the type of function being done, etc. One of the experts explained that there may be an implicit use of these suggestions already within the company. He emphasized that it might be interesting to give the information to practitioners to take from implicit to explicit and know what they are doing and not just doing it without awareness. This implicit use starts from the beginning in the onboarding of the company throughout the rest of the different areas. Another expert mentions that in her opinion the use of these suggestions depends on the project team. The dynamics within the teams are always different but when great teams are created, they tend to implement the majority of these suggestions and projects end up being successful.

6.4 Conclusion

In this chapter the proposed suggestions and the proposed implementation roadmap were evaluated and validated by four different experts in an expert session. The expert sessions were carried out with the four participants simultaneously in an online mode and was divided in three main parts.

This chapter starts by explaining how the expert session was constructed and how it was set-up. Following this, the experts discussed and validated the different suggestions on its applicability and if there were suitable for its aim. Next, the experts evaluated the roadmap developed and its applicability into the company. Certain improvements and additions were mentioned, which will not be developed further in this research since it is out of scope. However, it is recommended that the company decides how to apply these into their projects depending on their differences and characteristics. The use of the explanation of the different suggestions from previous chapters together with the roadmap itself, was agreed upon and decided to incorporate this information into the implementation roadmap. Apart from this, no other changes were made to the implementation roadmap. Consequently, the experts confirmed that the developed implementation roadmap is applicable in DPR Construction as well as in other construction companies, facilitating the implementation of flexibility recourses and its control.

In conclusion, both the suggestions proposed in the different phases of the implementation roadmap developed and the roadmap were validated by experts, being able to be applied into construction projects and companies.

7. DISCUSSION

In this chapter it will be discussed the findings of this research and the research limitations. the research carried out will be discussed. Understanding which were the limitations of the research helps to understand how these influence the outcomes of the research. This discussion will provide the bases for the conclusions and recommendations. This chapter is divided in two main parts, firstly the research findings, and following the research limitations. Within the limitations three main types will be discussed: limitations of the theoretical framework, limitations in the research methodology and the obtained data, and the limitations in the generalization of results.

7.1 Research Findings

Throughout this research thesis there was an aim to find the answer to a main research question: *How can flexibility in the planning of projects help manage design changes in construction projects?* To be able to answer this question an exhaustive literature review and interviews were carried out to create a theoretical background. As well, a correlation and factor analysis were done. This research used existing literature, practitioners' expertise, and practitioners experience to reach its purpose. The answer to the research question per se might differentiate from reality, since the base for this study was practitioners without much knowledge nor experience in flexibility recourses nor a flexibility management approach. To study the reality this should be applied to present existing projects and tests performed on it. Given there are time constrains and other type of limitations it was not possible to conduct this type of analysis for this thesis. Since the research is based in assumptions, it is not completely certain.

This research did answer the research question, but the answer was not a complete one. The answer provided information on how some elements from the literature that make the planning flexible, defined as flexibility recourses, affect the different causes of design change, helping to manage these design changes or not. The causality behind these relationships were based on assumptions, making this response not completely certain. But what this research did provide was that even though some flexibility recourses do help with design change causes, most of them evoke more changes in projects. This gives a strong basis for future research in the area.

Concerning the problem statement formulated in the first chapter of this document, it can be concluded that this research extends the existent knowledge on the capability of traditional project management in managing design change in project planning. It now can be said that traditional project management alone may be incapable of managing design changes, but for being able to manage design change a traditional approach is needed to some extent as a control measure for the effects of more flexible approaches. Furthermore, this research objective was to provide insights on how the implementation of flexibility in project planning helps manage design change causes. This has been achieved by the roadmap developed for the implementation of flexibility recourses in projects. Even though it was established that only one flexibility recourse helps managing design change causes: cross functional and multi-disciplinary teams. The rest of

the flexibility recourses have been concluded to evoke more design change causes, having the opposite effect than desired. Consequently, it is important to note that even though there were some, but little, frameworks and research on elements that enable flexibility, this research has created a framework on flexibility recourses to include in the planning of projects, which was non-existent before, adds up to the existent knowledge. Overall, the novelty of the research lies in the fact that even though flexibility recourses can be helpful for managing changes in projects, the use of this flexibility recourses evokes design change causes.

7.2 Research Limitations

This chapter discusses the limitations of this research conducted in this thesis. Firstly, the limitations of the theoretical framework will be discussed, following by the methodology and obtained data, and finally the limitations in the generalization of results.

LIMITATIONS IN LITERATURE REVIEW

When carrying out the literature review studies on traditional project management, flexibility in project management, flexibility in planning and scheduling, types of changes in projects, design changes in projects, causes of design changes, and effects of design changes, plenty of literature was analysed from different available search engines. However, due to time and resource limitations this literature review should not be considered as complete. Due to the extensive amount of literature, it is found impossible to have been able to collect all existing knowledge of literature available in these topics. Making that the answers to those sub questions based in literature review, may not be complete. With the topic on flexibility in project management and flexibility in planning, there is quite a limited amount of information for the construction industry, therefore literature based in other industries was used as well. These limitations on the available literature made the use of some assumptions needed. Meaning that the answers to sub-question 1, sub-question 2 and sub-question 3 are bound to constrains.

LIMITATIONS IN RESEARCH METHODOLOGY AND OBTAINED DATA

The research has several limitations which should be kept in mind when generating conclusions and recommendations. The analysis done have limitations on their internal validity and their external validity. Following it will be discussed the limitations of the correlations analysis and the obtained data.

Within the limitations of the correlation analysis, it will be discussed the ones regarding internal and external validity. Firstly, for the internal validity there are two main limitations. To begin with, the decision to perform the analysis using

the Pearson's correlation follows the assumption that the variables are measured at intervals or ratio. However, the Likert scale is in between a categorical scale and an interval scale. Which can lead to correlations being assessed to be significant when in reality they are not significant, leading to some limitations. Following, a second limitation lies in the direction of the correlations. The correlation analysis matrix does not provide with the direction in which the correlation goes, but assumptions must be made by the author to define these directions. These assumptions will create a limitation regarding the internal validity of the research.

Secondly, there are three main limitations regarding external validity of the correlation analysis. Because all the respondents of the survey were employees of the same company, DPR Construction, which follows the same culture in every project analysed the coverage error is present in this study. There is a limit in the generalizability of the research because of it. Additionally, even though the sampling error does not apply in this case, it is worth mentioning that the number of respondents can affect the validity of the study. It is recommended that a minimum sample of 80 respondents, and even though in this correlation analysis the quantity of respondents used were 115, the more respondents the more valid the results will be.

There are two main limitations within the obtained data, that are critical to highlight. Firstly, it is needed to understand that the data gathering was made using surveys, these surveys were arranged as an assessment of statements using a Likert Scale. Since the interpretation of such statements by the respondents is considered a fallout of the survey methodology, we need to consider that fidelity of the statements produced may be a limitation. Moreover, the fact that procurement used in this project has not been taken into consideration in this research nor data gathering process, this is considered an internal validity limitation of the data gathered.

LIMITATIONS IN GENERALIZATION OF RESULTS

Given that the research was conducted within one company it will be influenced by the management approach adopted normally in the company. In this case the Lean Construction methodology is used to some extent within the company, but the predominant approach is a more traditional and control focused approach. Moreover, the expert session for the validation was confirmed by all experts from the company itself, the four experts are practitioners of DPR Construction. This makes the session influenced by the management approach adopted in the company. Due to this, their views and opinions about the suggestions and the developed roadmap could have been biased given their own experiences in the projects undertaken in DPR Construction.

8. CONCLUSIONS

To achieve the research objective a main research question has been defined, in order to answer this main research questions several sub-questions have been formulated at the beginning of this document, in chapter 1. In this chapter the different sub research questions and the main research question will be answered.

How can flexibility in the planning of projects help manage design changes in construction projects?

Subsequently, to support this main research question, the following sub-research questions were formulated:

SQ1: What is flexibility in project management?

SQ2: Which enablers are used to add flexibility in the planning of projects?

SQ3: What are the types, causes and effects of changes in construction projects?

SQ4: Does a relationship exist between flexible recourses and causes of design change in projects?

SQ5: How can these flexibility recourses be implemented into practice?

8.1 Answering sub-research questions

SQ1: What is flexibility in project management?

Flexibility as a concept in project management has been around for some time now and has been widely proposed by researchers as an essential part of the duality that is needed to manage successful contemporary projects. The balance between flexibility and a traditional approach to project management has been stated to be the right combination of characteristics to reach a good and successful project in a dynamic and complex environment like the one is encountered in nowadays in projects. All of these

Flexibility is a broad concept and researchers have defined flexibility in several ways, this is summarized in Chapter 2 specifically in Figure 3 with different definitions of flexibility from different perspectives and focus. In these different definitions it can be observed a dual commonality between them, referring to uncertainty due to dynamic environments and the ability to respond quickly to changes. Subsequently, from these definitions an overall concept of flexibility was extracted, being “the ability to expeditiously react to the dynamic environment”.

Overall, the literature review conducted in this thesis has given the direction to this research and was useful attempting to define flexibility in the context of construction industry. Even though many definitions of flexibility in project

management were obtained from the extensive literature review, for this research it will be used a definition for flexibility in project management by Jalali Sohi (2018):

“The ability and readiness to deal with dynamics in a project”

SQ2: Which enablers are used to add flexibility in the planning of projects?

As established previously, today’s construction projects are filled with uncertainties due to the characteristic dynamic environment (Williams, 2005). Several scholars argue that traditional project management is not enough to succeed in projects, and a flexibility approach is needed for it. Although not much literature researches the use of flexibility in project management, evidence exists that some methodologies and tools are characterized by flexibility (Jalali Sohi, 2018).

It is needed to understand what has been taken as planning for this research, in order to understand the flexibility tools and practices which can be used in it. The Project Management Body of Knowledge states ‘planning’ as:

“The processes which establish the scope of the project, defines, and refines the objectives and designs the course of action to reach these goals”

The planning explores all aspects of the project as scope, time, costs, quality, communications, risk, procurement, etc. (Institute., 2017). Meanwhile the ‘scheduling’ is more than just adding tasks in a Gantt chart, it is an integral part of the project planning (Nicholas & Steyn, 2017). The scheduling concerns the activities, durations and resources for the project (Institute., 2017).

While carrying out the extensive literature review, some enablers for flexibility in planning were identified. These can be observed in Figure 5, Chapter 2. However, from these enablers 8 flexibility recourses were extracted:

Incremental planning, Iterative planning, continuous locking, contingency planning assuring several future scenarios, buffers, late locking, short feedback loops, and cross functional and multi-disciplinary projects.

SQ3: What are the types, causes and effects of design changes in construction projects?

Managing changes effectively is critical for the success of construction projects (Almasi et al., 2011; Anees et al., 2013). To manage changes proactively, Padala et al. (2020) argue that understanding change causes and effects can support project teams with this. Similarly, Charkhakan and Heravi (2012) states that the proper identification and assessment of changes is an important tool for change management.

In chapter 2, section 2.6 describes the types of changes, Figure 6 summarizes the possible types of changes existing in construction projects, extracted from literature. Being the different types of changes, or the different change factors, the following:

Project Location, Project Objectives, Project Scope, Project stakeholders, Contract Terms, Technology, Project Schedule, Project Cost, Project Resources, and Project Design.

Since the different types of change in construction projects was too broad of a scope to carry out in the available time, it was selected to continue studying specifically design changes. In chapter 2, section 2.8 the causes of design change were established by means of an extensive literature review, from which many causes were extracted, and contrasted with some exploratory interviews with practitioners from DPR Construction. From these mixed methods analysis, Figure 12 was created. These explain the main six factors for the design change causes:

Client Related, Design Related, Contractor Related, Process Related, Site Related, and External Related.

In the Figure 12 the complete detailed list of design change causes can be found.

Moreover, the effects or impacts of changes in projects are plenty. After carrying out the extensive literature review Figure 9 and 10, in section 2.9, summarize the different impacts. These categories of effects are mainly:

Impacts on time, impacts on cost, and impacts on people.

The categories for this “taxonomy” are divided in three “levels”, being “Level 1” the general category, “Level 2” a more specific aspect of the effect, and “Level 3” a very specific description of the effect of changes in projects. Within these three categories, several specific effects were encountered, however it is observed how many specific effects have the same overall impact on projects, “Level 1” effects. This can be observed in Figure 9 and 10.

SQ4: Does a relationship exist between flexible recourses and causes of design change in projects?

After performing the different correlation analysis and factor analysis, it can be observed in Chapter 4 the different results from this analysis. In section 4.5, Table 15, the different relationships between the variables are identified and analysed. The different relationships found between these two sets of variables that had a significant correlation were categorized in three types:

Positive Proactive Flexibility Recourses, Negative Proactive Flexibility Recourses, and Undefined direction correlations.

SQ5: How can these flexibility recourses be implemented into practice?

In Chapter 5 an implementation roadmap for the flexibility recourses was presented and validated in Chapter 6. The implementation roadmap consists in three simple steps in which different aims are targeted. The reasoning behind it is to start implementing the recourses which may be easier to implement in the eyes of practitioners. Once one phase is completed and normalized in the practice, the next phase can be put into practice. The implementation roadmap can be found in Figure 26, next to the developed roadmap further explanation of each proposed suggestions can be found.

As mentioned, the roadmap was validated through an expert session. In the expert session the implementation roadmap was discussed and validated by the experts. The proposed suggestions within the roadmap were discussed one by one

and validated by the experts in the same expert session. Based on the feedback received from the experts, it can be concluded that the developed implementation roadmap, as well as the proposed suggestions, can be implemented in practice and help with managing design changes.

8.2 Answer to main research question

How can flexibility in the planning of projects help manage design changes in construction projects?

In this research several elements that help adding flexibility into the planning of projects were recognized from literature. These were the base to creating a framework of flexibility recourses for planning in construction projects. In addition, a framework of the different causes for design changes was created using not only literature and previous research, but interviews with practitioners. These two frameworks were analysed in a quantitative way to find whether these two sets of variables had any relationship between them. This analysis was realized by carrying out a correlation analysis.

This analysis showed that 10 relationships existed between these two sets of variables. Within these, three main flexibility recourses were extracted: cross functional and multi-disciplinary projects, continuous locking, and incremental planning. For explaining these relationships these flexibility recourses will be separated into two groups.

The first one includes the flexibility recourse of cross functional and multi-disciplinary projects. This recourse has a direct positive effect, since when using it in projects it diminishes the design change causes in projects. If the causes of design changes diminish, so will do the emergence of design changes in the project. This flexibility recourse can be used as a proactive measure to managing design changes in projects.

The second one includes flexibility recourses as continuous locking and iterative planning. These two recourses have a direct negative effect, since when using them, they increase the design change causes in projects. Which if increased will create an increase in the emergence of design changes in projects. These two flexibility recourses cannot be used as proactive measures for managing design changes in projects. However, these methods can be used as a reactive measure for emergent design changes in projects. A way of controlling the negative effects these flexibility recourses bring, is the use of the traditional approach in balance with the flexible approach. The balance between these two approaches and practices may be the way to offset their negative effects.

Overall, it can be said that flexibility, in the form of flexibility recourses, can help managing design changes. This can be done by using flexibility as a proactive or a reactive measure, depending which recourse for flexibility it is being used.

9. DISCUSSION

This chapter will provide recommendations of different type. Firstly, recommendations for the practice will be provided following with recommendations for further research.

9.1 Recommendations for DPR Construction and practice

- It is recommended that the company does prioritizes a good balance between standardization of information and flexibilization of the information, without losing the availability and easy access of this information to all the parties involved in the project.
- Sending weekly or monthly reports to everyone involved in the project informing of the status of the progress, the planning and the risks encountered during the time in between reports. This contributes making information available and keeps everyone in the know of how the different tasks are running on site.
- As a way to increase the flexibility recourse of cross functional and multi-disciplinary projects, it is recommended to encourage involvement of all parties since the project starts and promoting team-building activities to generate better working teams in projects.
- It is recommended that the company raises awareness on flexibility recourses and flexible practices, by providing training and workshops. Practitioners need to recognize their own adopted flexible practices and make them explicit.
- It is encouraged that the company generates trials of flexibility use on projects and shares the information gathered from it, so practitioners can continue applying and learn from the experiences in other projects.
- As currently the lessons learned sessions are not being used in an efficient way, and information is not being further applied. It is recommended to search for another type of information sharing which is more effective for practitioners learning method.

9.2 Recommendations for further research

Given the exploratory nature of this research, there is room left for possible future research. The recommendations for further research are as follows:

- The scope of this research was set within the company DPR Construction, the same research could be carried in other companies to be able to compare if the results can be generalized or not.
- Also related to scope, the research was conducted in a construction company and focused on construction phase. It is recommended to conduct further research from other perspectives as clients or consultancy firms.
- Since this research scope was limited to only design changes, further research could focus on other types of changes in construction projects.

- It is recommended to perform further research in those relationships between design change causes and flexibility recourses which a logical causality was not found. There are different quantitative methods that can be done to understand, for example a mediation analysis between these two sets of variables would give the possibility of a significant effects between variables.
- Another aspect for which it is recommended to perform further research is to conduct more practical studies by implementing these flexibility recourses in different projects and analyse their effects on the project and whether the flexibility recourses can help manage changes.
- Since the flexibility recourses were extracted out of literature, and the limitations of literature were already established, the further research could be done to find other possibilities of flexibility enablers in the planning of projects.
- Studying how changing the way statements in the survey were constructed affects the results can be further researched, since the understanding of these statements can vary from person to person being a limitation of this research.
- Further research can study if the traditional mindset of the practitioners of the company has effects on the results of the correlation analysis and assessment of statements.
- The relationship between the two independent variables of flexibility and complexity could be studied in the future to understand how these affect the appearance of design changes.

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Appendix A – Agile Management

Agile Management started in the software industry in early 2000's, has been developing for the past 20 years and spreading to many industries since (Jalali Sohi, 2018), being the construction industry one of them (Owen et al., 2006). Agile Management is considered an “umbrella” concept since within this title there are multiple methodologies for management that share the aim of incrementing quality, flexibility, and value of software solutions. These were established as the solution for the problems the software projects was facing, such as delays, low-quality and cost overruns (Cooke, 2012). Agile approaches with iterative and incremental planning on short feedback loops have increased their influence within other areas of project management, as manufacturing and production, apart from the IT area (R. Turner, 2012). Stare (2013) claims that agile management and its practices are critical for the success of projects in the twenty first century. This is due to the ability of Agile's characteristics, such as iterative and incremental planning, as well as short cycles of feedback loops create the flexibility needed for coping with changes and dynamics in today's projects (Stare, 2013).

The Agile Manifesto suggests a transition from traditional to agile type of mentality, without discarding traditional methodologies. The values from the Agile Manifesto, as explained by Beck et al. (2001) compare traditional to agile way of working. These are: “Individuals and interactions **over** processes and tools”, “working software **over** comprehensive documentation”, “customer collaboration **over** contract negotiation” and “responding to change **over** following a plan” (Beck et al., 2001).

Among the different methodologies inside of the agile approach the most known and used tool is Scrum (Jalali Sohi, 2018). Scrum was developed by Jeff Sutherland in 1990's and was based on a rugby approach (Jalali Sohi, 2018). Scrum is characterized by a highly skilled team, with multiple areas of expertise, working together to develop a product during the process (Jalali Sohi, 2018). Scrum has same base as Agile Management with four main values and twelve principles (Beck et al., 2001). This is the reasoning behind its selection as the practice to focus on this research.

In Scrum there are three main roles: product owner, development team and scrum master (Schwaber & Sutherland, 2011). Based on the Scrum Guide by Schwaber and Sutherland (2011) there are five events within Scrum approach: the sprint, sprint planning, daily scrum, sprint review and sprint retrospective. The sprint is the core of scrum, it takes between one and four weeks, with a clear aim which does not change during the Sprint (Schwaber & Sutherland, 2011). These is planned in advance in the Sprint Planning. The Daily Scrum is a daily meeting which lasts 15 minutes, and its objective is to monitor the progress, giving the chance to the team to adapt, or change, the plan if needed (Schwaber & Sutherland, 2011). Sprint Review is a meeting done at the end of the Sprint, where increment is checked, and next steps discussed. Finally, Sprint Retrospective is done after the Sprint Review and before the planning of next Sprint. Lessons learned from the Sprint are reviewed in this meeting, and a plan for enhancements drawn (Schwaber & Sutherland, 2011).

The Sprint creates 3 artifacts: Product Backlog, Sprint Backlog and Increment (Schwaber & Sutherland, 2011). These are explained by Schwaber and Sutherland (2011) being the first a list of the requirements for the product, the second one contains the selected items of the Product Backlog for the scrum and the plan to follow, and the latter is the result of a sprint as a viable product. Scrum framework is explained graphically in Figure 30.

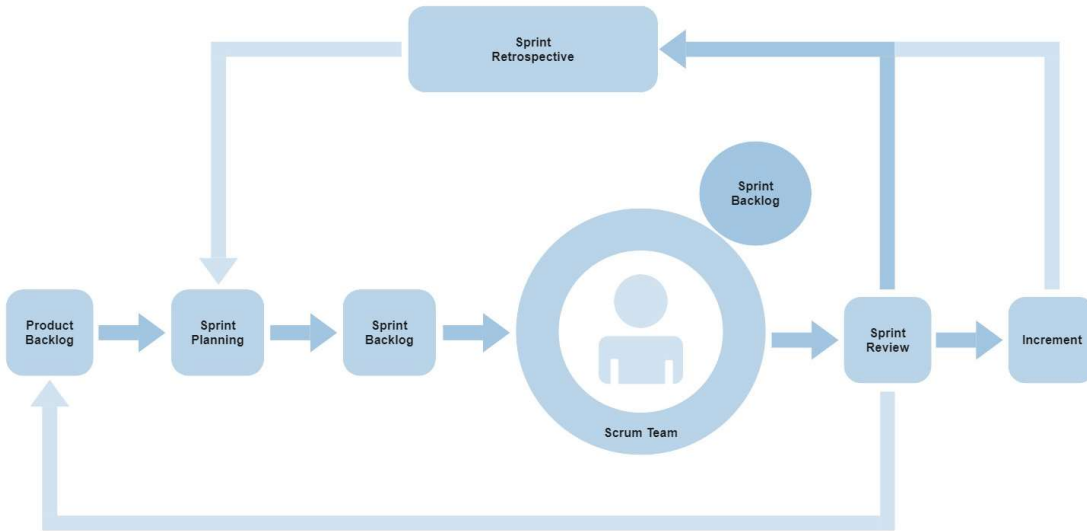


Figure 30 - Scrum Framework adapted from "What is Scrum?" (n.d.)

Appendix B – Lean Management

The term “lean” was first used to name a production system for vehicles, capable of producing more and better units in less time and space, while using less labour hours (G. Ballard & Howell, 2003). As defined by Hamzeh (2011) “Lean is a business philosophy and a system for organizing and managing corporate processes including product development, design, production, operations, supply chain, and customer relationships to increase value and minimize waste. Lean is a perpetual quest for perfection pertinent to organizational purpose, business processes, and developing people” (Hamzeh, 2011). G. Ballard and Howell (2003) argues that from this production system new concepts and techniques were identified as “Just in time” deliveries, “pull versus push” mechanisms, increasing transparency, etc. Due to the fact that Lean Management comes from a production background, there was substantial resistance from the construction industry to apply these techniques in construction projects. Some argue that Lean Management tries to make construction more like manufacturing and generate increased standardization. However, Howell and Ballard (1998) claim that “the goal of lean thinking describe the management of dynamic projects” (Howell & Ballard, 1998). With the passing of time different lean techniques have been introduced in practice, with the aim to enhance project management, eradicating waste, boosting planning efficiency and reliability, improving productivity and generating maximum value (AlSehaimi et al., 2014). Lean thinking has clear principles: “stopping the line, pulling product forward, one-piece flow, synchronize and align, and transparency” (Howell & Ballard, 1998). Bluntly, it can be said that “Lean” is a process that aims for maximize value, minimize waste and deliver the product (G. Ballard & Howell, 2003).

The Lean Project Delivery System Model is formed by five main phases, being: project definition, lean design, lean supply, lean assembly and use (G. Ballard & Howell, 2003). Within the Lean Project delivery System several techniques and applications are included, such as: Last planner system of production control, work structuring through pull scheduling, negative versus positive iteration in design, and the application of lean rules and tools to precast concrete fabrication (G. Ballard & Howell, 2003). The best known technique is the Last Planner System, which has been proved as a highly useful tool for managing construction projects, and the continuous control of planning efficiency (AlSehaimi et al., 2014). This technique was developed as a way to increase effectiveness in planning and control, by increasing probabilities of delivering on time, making the program more predictable (H. G. Ballard, 2000). The Last Planner System is being used widely throughout the world, and improvements in project delivery times, labour productivity, safety and quality have been observed (Formoso & Moura, 2009; Porwal et al., 2010).

Last Planner System is a tool for planning, monitoring, and controlling projects that follows lean principles. Its primary function is the process of collaborative planning which involves last planners, making the plan more detailed as the team gets closer to execution (Porwal et al., 2010). In the research by Kalsaas (2012) the differences with traditional planning are highlighted, it claims that Last Planner System assumes “that the uncertainty of making predictions for the point at which all constraints are out of the way so that work can commence can only be removed in the final instance by the team leader responsible for providing the labour needed for any given task” (Kalsaas, 2012). The collaborative planning

environment promotes exchange and continuous resolution of constraints, increasing efficiency in workflow and accurate strategies for buffering (G. Ballard et al., 2020). This system has helped construction projects improve reliability of planning, performance and workflow (Hamzeh, 2011). In the literature of G. Ballard et al. (2020) it has been planned an extension of the Last Planner System, based on the uncertainties that contemporary projects deal with, which enhances project execution by flexible and proactive management of changes throughout the project. It develops a decision process which lets the team early in the project without much knowledge, be able to assess whether the project can be delivered in time and cost (G. Ballard et al., 2020).

Kalsaas (2012) tries to elucidate what the Last Planner System involves, establishing five steps for its implementation:

- Preparation of a “Master Schedule” including all the major milestones in the project.
- Phase Planning, using reverse-phase scheduling allowing to be carried out at “the last responsible moment”, minimizing unnecessary accumulation of work in process.
- Preparation of a “Lookahead Plan”.
- Preparation of a “Weekly Work Plan” in consultation with the last planners, which is feasible, and all the parties are committed to it.
- Monitoring the execution and preparation of the report establishing the “Percentage Planned Completed”.

AlSehaimi et al. (2014) explains that when these steps are systematically implemented, major benefits to construction planning are achieved. What is understood as the “Last Planner” is the person or group of persons in charge of production unit control, the ones in charge of the completion of individual assignments in operations level (AlSehaimi et al., 2014). Some scholars address the necessity of incorporating daily meetings into this process (Kalsaas, 2012) Through the “lookahead planning”, the “make-ready” process, the “weekly work planning” and by the commitment of the leaders of the work teams involved, is how reliability is enhanced in projects which apply this tool (AlSehaimi et al., 2014; Formoso & Moura, 2009).

Being a tool within Lean Management, the Last Planner System advocates for “planning in greater detail as time gets closer to executing the work”, “identifying and removing work constraints ahead of time to increase reliability of work plans”, “developing the work plan with those involved in the tasks”, “making work execution based on coordination and negotiations with the different teams and trade partners”, and “learning from planning failures by finding root causes and preventive actions” (H. G. Ballard, 2000; Hamzeh, 2011)

In recent times there have been studies that research the possibilities of using the Last Planner System as a tool for managing dynamic environments in projects. On one hand the study by G. Ballard et al. (2020) evaluates the possibility of using options in project plans as a way to add flexibility in order to cope with uncertainty and dynamics in projects. In it, it is demonstrated that these options enable beneficial actions for future uncertain events, creating quick adaptation to real-time demand information, leading to reduced times and costs, that the traditional reactive planning approach (G. Ballard et al., 2020). Aspects as postponement decisions and buffering systems within the Last Planner System have shown to better handle changes in projects, this could be explained by the fact that this tool implies constant adaptation

to new information of the project, as well as changes in objectives or new pathways to objectives are discovered (G. Ballard et al., 2020).

On the other hand, in the research by (Vaagen & Ballard, 2021) claims that essential aspects of lean construction as flexible set-based design principles assist in producing several solutions for changing conditions. In this research flexibility is also embedded in the use of options, staggering the planning process depending on the information arrival. This planning requires substantial coordination between stakeholders, in order to align information in a constant manner (Vaagen & Ballard, 2021).

Appendix C – Critical Chain Theory

Critical Chain Theory arises in 1997 in the novel, with the same name, by Eliyahu M. Goldratt. In this book Goldratt proposes an approach for project management based in his already existent Theory of Constraints. The reasoning behind the development of Critical Chain Theory is based on the chronic problems that projects are encountered and have not been able to solve with other practices (Rand, 2000). In his research Rand (2000) highlights these project problems like late completion and over spending, within other non-desirable factors normally seen by project managers. Similarly, Leach (1999) describes Critical Chain Theory as a way to reconfigure project management and its planning to abolish these common problems that lead to poor performance of the project.

Critical Chain Project Management is an extension of Goldratt's Theory of Constraints specifically adapted for project management and its environment. Theory of Constraints is a tool to manage production systems grounded on the principle that each system has a constraint, and the only way to improve the performance of the system is by the enhancement of the performance of the constraint resource (Raz et al., 2003). Goldratt suggests that his Theory of Constraints is the solution for these problems (McKay & Morton, 1998). And Critical Chain Theory, being its application in projects (Rand, 2000), is the alternative to traditional methods for project planning and control, such as the ones found in standardized practices and bodies of knowledge (Raz et al., 2003). Thus, the focus of Goldratt's Critical Chain is the planning of projects, since he argues that the greater costs in projects are a consequence of time overruns and not budget overruns (McKay & Morton, 1998), and that the causes for it are the misuse of the safety times inside of the schedule and the estimated times for the different activities (Rand, 2000). Critical Chain focuses on developing project management and reducing the activity times and the overall project duration, in order to meet the expected project performance (Leach, 1999).

The emphasis in Critical Chain is focusing in the schedule of the project (Leach, 1999), enabling a much predictable and shorter project lead times as a way to enhance the possibility of winning biddings, as well as reducing costs and being able to easier follow specifications (Stratton, 2009). The Theory of Constraints methodology uses three types of buffers: feeding, resource and project. This buffer mechanism gives a tool for monitoring the project and setting dates in a more realistic way (Herroelen & Leus, 2001). Herroelen and Leus (2001) argues that Critical Chain and Buffer Management attempt to minimize the effects of Parkinson's Law, which establishes the tendency of finishing the work at the last moment when it is possible to complete it before, through building a schedule which target duration estimation is based in a 50% confidence level. This is done by the elimination of due dates, milestones, and multitasking (Herroelen & Leus, 2001).

As mentioned before, Critical Chain seeks to describe how Theory of Constraints can be applied to project management (Rand, 2000). The Theory of Constraints as explained by Rand (2000) and Leach (1999) is based on five steps: "Identify the system's constraints", "decide how to exploit the system's constraints", "subordinate everything else to the above decision", "elevate the system's constraints", and "going back to step 1 if constraints have been broken in previous steps"

(Leach, 1999; Rand, 2000). These is the main ideal behind Critical Chain Project Management, but it is applied to practice by removing the hidden safety in the durations of the different activities. This is used as a protection from starting late on activities, or what is understood as Student’s Syndrome, and from keeping working during the whole activity duration when it could be finished before. These safety times are afterwards placed at “key points” as buffers to absorb possible delays (Long & Ohsato, 2008). There are three different types of buffers: project buffer, feeding buffer, and resource buffer.

Project buffer is the one placed at the end of the critical chain and will protect the entire project against exceeding the completion date (Long & Ohsato, 2008). By adding this project buffer the total duration of the project does not increase and is promoted to add it as an activity with assigned resources in the Gantt chart, as a way to communicate the inherent uncertainty in projects (Raz et al., 2003). Furthermore, feeding buffers are placed in-between non- critical and critical paths, to protect against disturbances (Long & Ohsato, 2008) and path merging (Leach, 1999). These can be observed in a graphical way, using a Gantt chart diagram, in Figure 31. Lastly, resource buffers are needed to deal with critical resources, and protect the critical chain for resource availability. Resource buffers are a virtual task inserted in the critical chain and does not consume resources nor adds time or cost to the project (Raz et al., 2003).

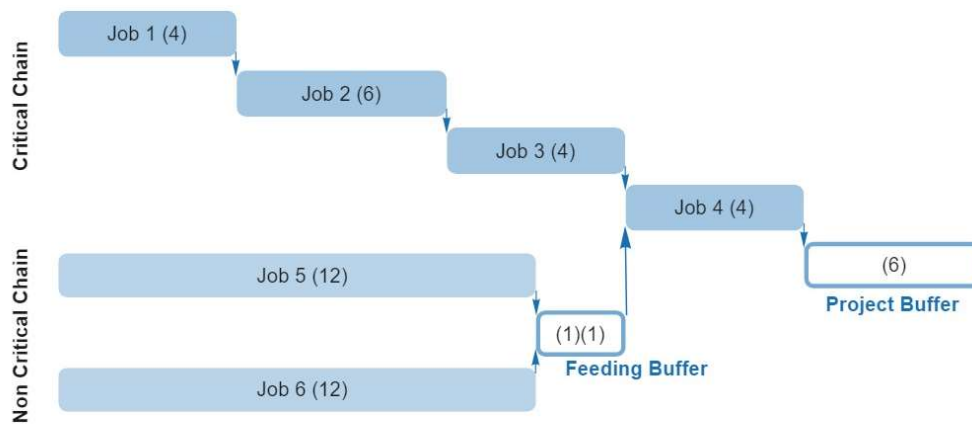


Figure 31 - Critical Chain Theory

The different buffer types are essential for Critical Chain theory, since the size of the project buffer should mirror the amount of protection needed against uncertainty in the overall task durations (Raz et al., 2003). Commonly the buffer size is set at a 50% of the chain length (Long & Ohsato, 2008). On the other hand, the size of feeding buffers should be appropriate for the requirements of the non-critical paths and its size can be adjusted as desired (Raz et al., 2003). If the critical path changes, it is required to re-engineer the schedule and resource buffers, redistributing safety margins (McKay & Morton, 1998).

The reasoning behind Critical Chain is based on the fact that the original estimated durations are done on the likelihood on completion of 95%. Goldratt argues that these should be reduced to 50%, and the difference between these estimates located in the project buffer (Raz et al., 2003). Goldratt argues that in most cases the safety margin included in the 95%

likelihood will not be needed to complete the task and should be completed sooner than it is scheduled. And given that the safety margins are property of each task, if they are not needed, or used, they are wasted (Raz et al., 2003). Therefore, if time is gained during the project because a task was finished before the estimated time, it is lost. And tasks which get extended from the scheduled time, will pass on the delay in full to the next tasks. These affects the project completion date, even though safety margins planned within the schedule should be enough. This practice aims at improving schedule performance, reducing project changes and major causes of cost overruns as an effect. This is accomplished by changing the planning of the project and using the buffers as a project control system (Leach, 1999).

Critical chain has acted as an “eye-opener” in project management practice, clearly identifying the interaction between time requirements of activities, precedence relations and resource availability, as crucial factors impacting the duration of a project (Herroelen, Leus, & Demeulemeester, 2002). Leach (1999) claims that Critical Chain provides a meaningful step in the improvement process of Project Management Body of Knowledge.

Appendix D – Interview Protocol for Exploratory Interviews

EXPLORATORY INTERVIEWS

This semi-structured exploratory interview is conducted in DPR Construction, and the participants involved are PSPP within DPR Construction. The aims of conducting this interview are:

1. To identify the changes experienced in practice and their type, causes and effects.
2. To identify the current practices and status of flexibility in company's projects.
3. To diminish the scope of the research by defining the type of change that will be focused on.

General Information:

Subject: Exploratory Interview

Interviewer: Natalia Lukin

Interviewee:

Date:

Time:

Introduction:

- MSc Construction Management & Engineering student at TU Delft
- Graduation research
- Context and Objective of research

General Questions:

- Which area do you currently work in?
- What is your current role? What do you do in this role?
- How many years of experience do you have?
- Do you have any knowledge on practices as Agile Management, Scrum, Critical Chain Theory, Lean, etc.?
 - *Do you use these practices? Why / Why not?*
 - *Are these practices used in the company? Why/Why not?*
- How are changes processed in the project organization?
- How is it disseminated to everyone to whom it is relevant?

- Who decides on change requests? How do they decide on them? Are there any checks that must be in place?

Changes in Projects

- How often do you see changes in projects?
- Which changes in projects do you commonly recognize?
 - Is there any change which appears more often?
- In which phase of the project do you recognize most changes happen?
- What tend to be the causes for these changes?
- Which do you recognize as effects of such changes?
 - What impact do these changes have on the schedule?
 - How would you solve/diminish these impacts on schedule?
- In case of having to choose only one type of change for this research, which one would you choose? And why?

Flexible Project Management:

- What according to you is flexibility in project management? And in planning?
- Have you used any practices when planning which increase flexibility in project management? (Agile, Critical Chain Theory, Scrum, etc.)
 - *If yes, could you name some examples?*
 - *What benefits do you find when using flexible techniques? Drawbacks?*
- To what extent was it possible to manage changes when using this flexible practices/tools?

Appendix E – Exploratory Interviews Transcript

Questions	Interviewee 1	Interviewee 2	Interviewee 3
General Questions			
Which area do you currently work in?	I am in the DACH area	I'm a planner for our one of our projects in Switzerland	Scheduling and Planning
What is your current role? What do you do in this role?	I am the DACH Regional Planner, I am part of basically any of the projects in DACH. I work with the planning managers on each of the projects, assisting them with compliance, strategic training, ensuring the project control is maintained. Assisting with negotiations with clients and tender programs.	I am the person who created the initial schedule and I've been updating it since, adding changes, doing delay claims, etc. Also helping the team with like almost day-to-day planning and weekly planning, making sure things happen as they need to happen. That comes with a lot of sub contractor involvement and communication too.	I am the planner for one of the projects. I do many things, basically maintaining and making the plan for the project. Comparing and taking out all the trades with our team, communicating the plan, analyzing if there are road blocks coming and try to solve them. A lot of coordination.
How many years of experience do you have?	24 years in process engineering and construction.	5 years working in planning construction projects	7 years working in construction projects
Do you have any knowledge on practices as Agile Management, Scrum, Critical Chain Theory, Lean, etc.?	In Lean, since it is used in the company, but I have never been formally trained on it. I use it by default.	Lean, we use it a lot in DPR, and I even took a course on it as an extension learning in the company.	Lean, we use in DPR. Last System Planner, it basically links everything and is more flexible than P6.
How are changes processed in the project organization?	It varies depending in the contract type, mostly. In a traditional contract, where the client is responsible for the design, every change will be consider a variation on the contract. The change comes through the design manager, and it will be assessed on costs and program (DPR with subcontractors related to the change), and return to client's representative. The terms of the variation are negotiated, depending it involves time or money. Once we come to an alignment, the change is instructed. However, in a DBB contract it gets quite murky, and the process of changes is very difficult to track. Since the design team will be delivering designs when there is enough information to the trade to start procurement and construction, and afterwards you find out by the subcontractor that there has been a change in the design to what was the contract based on the first information. So changes happen from the original price because of the update, and new quantities and new price will be established and DPR has to absorb it. We tried a technique which was design to a price, so that changes will not affect the original one, but for this you need people who has the experience to do it. However it will be a very powerful process if we knew how to implement it.	We are working with the design partially done by DPR itself, so it is evolving on the go a lot of times. The design team send us amendments with changes, we analyze it with subcontracts which are in charge or hired for the specific tasks that the change compromise, and from there we evaluated the impact of the change in terms of time. And the same with the person in charged of budget and project management.	We do meetings to discuss about the changes, if they have benefits or impacts, and analyze how to adapt the schedule and the cost to include it. Once the change is agreed within the team, it is communicated to the client who has to accept it.
How is it disseminated to everyone to whom it is relevant?		The change is evaluated, and communicated to everyone who has to be involved in it. This is done by the project management and the planning team.	We communicate by Teams, by email, and assign task by an internal platform of DPR, we create meetings to get together and discuss the information of the change.
Who decides on change requests? How do they decide on them? Are there any checks that must be in place?		In this project the changes are created by the design team, and the rest of the team adapts to it. So we evaluate the changes and report the impacts they may have.	Sometimes changes comes from clients, sometimes from subcontractors who notice improvements that could be made, or design teams, etc. There need to be an agreement from the team and the client.
Changes in Projects			
How often do you see changes in projects?	It could be said is a daily occurrence or weekly occurrence. But it only formalizes itself when more time or money is needed. But normally it happens in waves.	In this project in particular, we are having many changes in a daily basis.	Not that often, at least in the project I am currently working. It could be said we have a change every week.
Which changes in projects do you commonly recognize?	Every time there is an update on the level of detail design, we have a lot of changes once we start coordinating with the different trades, and from each change subsequent changes from it. Apart from that, there can be an appearance of scope changes because the client got a tenant, and with it comes changes or adaptations.	In this case the design was absorbed partially by DPR, so it has been having a lot of revisions for each task and a lot of updates on the different designs of different engineering.	At the beginning the schedules are not very well defined, and when breaking down in parts you realize you may need a bit more time of what was expected. As well, the need for adaptations between countries tends to appear very often.
In which phase of the project do you recognize most changes happen?	I would say it varies, depending in the client and depending on the contract. But in the majority in the execution.	I think that in execution, or at least for this project it was.	In the execution.
What tend to be the causes for these changes?	Lack of information in the initial stages, which lead to poor design and lack of information for the design team, which ends up affecting everything.	The poor design at the beginning, so now the design is changing constantly, and the specifications of the different equipment to be installed.	The client wants changes for the end customer of the building, so the design may change or the scope may change. Lack of quality in projects as well, acts as a cause.
Which do you recognize as effects of such changes?	It can be extensions in time, but is not like all of them will create delays or extensions. And it affects cost and budget as well.	They require a lot of work for evaluating and understanding of the impacts. These are mainly in management of time and resources.	Mostly, delays in the works, reworks are not too often seen.
What impact do these changes have on the schedule?	Eat in the sequence of tasks, but not always may lead to extensions and delays.	Having to alterate the schedule, and possible delays on the original one.	Delays in the schedule or extra time.
How would you solve/diminish these impacts on schedule?	Using up floats, re-sequencing by using lean techniques and refine a sequence in the planning, adding more labour, etc. Also, check when the change would be better to be implemented, out of the critical paths that are running in the area.	To have less impact, have better coordination within the parties. Use the tools we have for creating a more finished design before we go into execution. In schedule: be quick to react or respond to changes.	Create mitigation plans, meetings with clients and subcontractors, try to re-sequencing the tasks, try to the changes are not impacting the end date of the schedule. Coordination and collaboration is the key of the project success.
In case of having to choose only one type of change for this research, which one would you choose? And why?	Change due to coordination in design	Design changes which affect the whole design or a lot of parts of the design.	Changes because of different countries, normatives and laws, as well as different types of working with international subcontractors.
Flexible Project Management			
What according to you is flexibility in project management? And in planning?	Flexibility, I think is about the whole team being able to move with the change, to be able to move in unison and quickly. And in planning, if the latter happens it will be way easier.	I think the opposite of rigidity. In DPR the roles and responsibilities tend to be flexible, we fill in gaps as needed.	Open to new ideas and collaboration, a way to be supportive of your team.
Have you used any practices when planning which increase flexibility in project management? (Agile, Critical Chain Theory, Scrum, etc.)	Not formally, I am aware there are some theories but I don't use them. And softwares, I have tried a lot but I do not believe there is a difference, the important aspect is who is using the tool and which type of information is putting on it.	We normally use BIM 360 plan, and we do constant meeting with the different subcontractors to plan in advance what is in the schedule for the next weeks. Coordination of the whole team. But a balance between this flexibility and more control practices are needed for legal purposes with the contractual aspects.	Bull planning sessions, dashboards and continuous meetings to plan for the next week.
What benefits do you find when using flexible techniques? Drawbacks?	Since I have not used I cannot say much. But about Lean, it goes too much into detail and we are not usually geared for the potential additional administrative burden of using this. In summary, often we are not trained and resourced, and neither are our trade partners to implement on of these practices.	I find that some softwares are too difficult to use with other people, since they tend to focus on total control. So using other tools that are more flexible makes it easier to coordinate and communicate with subcontracts and the team.	Increases coordination between the different parties in teams. Negative aspects were not found on the practices that this interviewee uses.
To what extent was it possible to manage changes when using this flexible practices/tools?	Have not used them, so I am not able to tell.	For changes I do not know how flexible you want to be, since you do not want things to fall through the cracks or loose control. But I have not tried it, so I do not have the information to answer this question.	The most you know about a change, by gathering information from several people that are related to the change and the tasks in question, it will be easier to decide for the change and understand the impacts of it in the schedule and planning, as well in the overall project management.

Table 19 - Exploratory Interviews Transcription

Appendix F - Correlation Analysis Survey

Survey Graduation Internship - Flexibility and Design Changes

For graduating from Delft University of Technology, in MSc Construction Management and Engineering, I am conducting a research thesis into flexibility in planning and changes in construction projects within DPR Construction.

The purpose of this survey is to evaluate the relationship between flexible strategies for planning and scheduling and causes of design changes. The results will provide an overview of these relationships (or lack of them) and whether flexibility recourses could have an effect in coping with design changes.

The survey includes 5 main sections. All questions have to be answered for one specific project, please do select the most recent project you participated in or the project you are now working in. The answers to these questions need to be based in this specific project.

The sections of this survey are:
Section 1: General personal questions.
Section 2: Characterization of the project.
Section 3: Understand the design change causes in projects.
Section 4: Assess flexible tendencies in the planning and management of projects.
Section 5: Optional Questions to assess flexibility in Project Management.

The entire survey will take about 15 minutes. All the information provided will be kept confidential and results

*** Required**

Personal Information

1. What Is the highest level of education you have acquired? *

Short-cycle tertiary education

Bachelors

Masters

PhD

Other

2. What is your current role/position in the company? *

Planning Manager

Project Manager

Figure 32 - Correlation Analysis Survey - Phone Interface

Survey Graduation Internship - Flexibility and Design Changes

For graduating from Delft University of Technology, in MSc Construction Management and Engineering, I am conducting a research thesis into flexibility in planning and changes in construction projects within DPR Construction.

The purpose of this survey is to evaluate the relationship between flexible strategies for planning and scheduling and causes of design changes. The results will provide an overview of these relationships (or lack of them) and whether flexibility recourses could have an effect in coping with design changes.

The survey includes 5 main sections. All questions have to be answered for one specific project, please do select the most recent project you participated in or the project you are now working in. The answers to these questions need to be based in this specific project.

The sections of this survey are:

Section 1: General personal questions.

Section 2: Characterization of the project.

Section 3: Understand the design change causes in projects.

Section 4: Assess flexible tendencies in the planning and management of projects.

Section 5: Optional Questions to assess flexibility in Project Management.

The entire survey will take about 15 minutes. All the information provided will be kept confidential and results will be published anonymously.

If you have any questions about the survey or you are interested in the results of this research, you can contact via the following details:
natalial@europa.dpr.com or +31643193378

Thank you very much for your cooperation!

Sincerely,

Natalia Lukin

2. What is your current role/position in the company? *

Planning Manager

Project Manager

Superintendent

Project Engineer

Other

3. How many years of work experience do you have in total? *

Less than 5 years

Between 5 and 10 years

Between 10 and 15 years

Between 15 and 20 years

Between 20 and 25 years

Between 25 and 30 years

More than 30 years

4. How many years of work experience do you have in your current role/position? *

Less than 5 years

Between 5 and 10 years

Between 10 and 15 years

Between 15 and 20 years

Between 20 and 25 years

Between 25 and 30 years

More than 30 years

Next

* Required

Personal Information

1. What is the highest level of education you have acquired? *

Short-cycle tertiary education

Bachelors

Masters

PhD

Other

* Required

Characterization of Selected Project

In this second section of the survey it is aimed to creating a clear picture of the selected project.

5. Name of Selected Project *

Enter your answer

6. Location of Project *

- USA: NW
- USA: SW
- USA: CEN
- USA: NE
- USA: SE
- Europe: DACH
- Europe: BENELUX
- Europe: NORDICS
- Other

7. Phase of Project *

- Tender
- Pre-construction
- Construction
- Close-out
- Other

8. Which type of client does this project have? *

- Public
- Private

9. Which is the project expected duration? *

Enter your answer

10. Please characterize the project by rating the following statements. *

	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
There is uncertainty in the technological environment of the project.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is a good collaboration with the client.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is a high dependency between tasks in the project.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A high number of external stakeholders are involved.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Project size based on its cost is considered a relatively big project.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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* Required

Design change causes in projects

In the third section of the survey statements about causalities of design change must be rated regarding its frequency of appearance in the selected project.

11. Client-related causes for Design Changes in projects *

	Almost Always	Sometimes	Every once in a while	Rarely	Never	I do not know	Not applicable
There are changes in requirements/specifications in the project.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scope changes by the client appear in the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New technology is introduced over the timeframe of the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are omissions of the scope given by the client	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The contract type chosen was not appropriate for the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The brief given by the client is unclear	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Changes arise to increase the engineering value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. Design-related causes for Design Changes in projects *

	Almost always	Sometimes	Every once in a while	Rarely	Never	I do not know	Not applicable
The design was realized under tight time constraints	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There were modifications to the design once the project started	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Design errors appear during the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Design omissions are encountered in the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The project has an outdated design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Information from any given source provided to designers is inadequate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Designer team is not involved during the construction phase	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are discrepancies between contract documents in the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is a lack of awareness of regulations or requirements of local authorities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The project has incomplete drawings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

13. Contractor-related causes for Design Change in projects *

	Almost Always	Sometimes	Every once in a while	Rarely	Never	I do not know	Not applicable
There are requests to use available materials in the market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In the project alternative construction methods are used	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are incomplete plans and specifications in the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
During the project the contractor requests or suggests improvements for the buildability of the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are insufficient working drawing details for the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14. Process-related causes of Design Change in projects *

	Almost Always	Sometimes	Every once in a while	Rarely	Never	I do not know	Not applicable
There is a poor project organizational structure	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The project experienced unpredictable circumstances during construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is a lack of coordination and communication	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are fragmentation/availability of information within the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are multiple/not aligned schedules in the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is an overlapping of design and construction phase	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. Site-related causes of Design Change in projects *

	Almost Always	Sometimes	Every once in a while	Rarely	Never	I do not know	Not applicable
There are changes in the ground conditions during the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Changes in the site layout and/or access to it arise during the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are differing site conditions during the project than planned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16. External-related causes of Design Change in projects *

	Almost Always	Sometimes	Every once in a while	Rarely	Never	I do not know	Not applicable
There are changes in economic conditions during the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Changes arise during the project regarding government policy/issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are problems with neighbors during the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The project suffered with severe weather conditions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are unexpected changes in material availability during the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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* Required

Flexibility strategies in planning and scheduling

In the fourth section of the survey statements about flexibility in planning and scheduling must be rated regarding its frequency of use in the selected project.

17. How often do the following statements apply for the selected project? *

	Almost Always	Sometimes	Once in a while	Rarely	Never	I do not know	Not applicable
A detailed schedule is not made at the beginning of the process, but a weekly scheduling exercise is carried out.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A detailed schedule is not made at the beginning of the process, but a monthly scheduling exercise is carried out.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The plan is adjusted in a weekly manner as the project advances to fulfill the requirements of the project.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The plan is adjusted in a monthly basis as the project advances to fulfill the requirements of the project.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Decisions in the project are continuously postponed until the required information is available.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Different options are created within the planning and project schedule for the project.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
For this project duration of tasks were shortened and this time allocated as floats/slack next to activities influencing the critical path as buffers.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

For this project duration of tasks were shortened and this time allocated as floats/slack at the end of the project as spare time.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The schedule was extended to add some spare time at the end of the project as a buffer.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
During the project it premature decision making is avoided until the information needed is available (making decision at the last responsible moment).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The team has weekly meetings in which feedback is given on the activities taking place.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The team has monthly meetings in which feedback is given on the activities taking place.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is an involvement of all parties and disciplines in the project working together as a team.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The information is shared and available for all the different parties in the project.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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Optional Questions to assess flexibility in Project Management.

The following questions aim to collect more information into the practices established at DPR's projects.

18. What according to you is flexibility in project management?

19. What according to you is flexibility in planning?

20. Have you used any practices when planning which increase flexibility in project management? If yes, name examples.

21. What benefits do you find when using flexible techniques?

22. What drawbacks do you find when using flexible techniques?

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Appendix G - Correlation Matrix

CORRELATION ANALYSIS MATRIX																
			Incremental Planning	Iterative Planning	Continuous Locking	Contingency Planning	Buffers	Late Locking	Short Feedback Loops	Cross functional and multi-disciplinary teams						
			A detailed schedule is not made at the beginning of the process, but a weekly scheduling exercise is carried out.	A detailed schedule is made at the beginning of the process, but a monthly scheduling exercise is carried out.	The plan is adjusted in a weekly manner as the project advances to fulfill the requirements of the project.	Decisions in the project are continuously postponed until the required information is available.	Different options are created within the planning and project schedule for the project.	For this project duration of less than one week and the time allocated to activities is influenced by the critical path as buffers.	For this project duration of less than one week and the time allocated to activities is influenced by the critical path as buffers.	The schedule was extended to add some spare time at the end of the project as a buffer.	During the project the information needed (making decision at last responsible moment).	The team has weekly meetings in which feedback is given on the activities taking place.	The team has monthly meetings in which feedback is given on the activities taking place.	There is an involvement of all parties and a discipline in working together as a team.	The information is shared and available for all the parties in the project.	
Client-related	There are changes in requirements/specifications in the project	Pearson Correlation Sig. (2-tailed) N	-0.075 0.420 107	0.009 0.928 107	0.302 0.001 111	0.128 0.130 115	0.182 0.140 113	0.069 0.375 102	-0.064 0.402 102	-0.072 0.370 106	0.116 0.179 104	0.101 0.283 115	-0.023 0.805 114	0.036 0.203 115	0.051 0.107 115	
	Scope changes by the client appear in the project	Pearson Correlation Sig. (2-tailed) N	-0.030 0.757 106	0.025 0.796 106	0.196 0.040 116	0.036 0.705 114	0.102 0.236 102	0.113 0.236 102	-0.069 0.492 102	-0.051 0.609 105	-0.130 0.167 104	0.111 0.261 104	0.060 0.488 113	-0.002 0.984 113	0.131 0.190 114	0.201 0.032 114
	New technology is introduced over the timeframe of the project	Pearson Correlation Sig. (2-tailed) N	0.105 0.243 105	0.160 0.081 105	0.003 0.927 108	0.009 0.931 109	0.002 0.927 113	0.230 0.015 101	0.135 0.178 101	0.135 0.094 100	0.135 0.212 100	0.046 0.046 104	0.007 0.112 104	0.112 0.112 112	0.153 0.083 112	0.199 0.035 113
	There are omissions of the scope given by the client	Pearson Correlation Sig. (2-tailed) N	0.011 0.154 105	0.034 0.160 105	0.160 0.075 108	0.272 0.005 112	0.065 0.725 111	0.055 0.101 105	0.227 0.345 100	0.247 0.247 105	0.403 0.112 105	0.403 0.112 111	0.491 0.160 112	0.283 0.055 112	0.805 0.256 112	0.107 0.212 112
	The contract type chosen was not appropriate for the project	Pearson Correlation Sig. (2-tailed) N	0.178 0.65 90	0.311 0.80 90	-0.009 0.931 92	-0.001 0.991 92	0.273 0.007 96	0.035 0.738 94	0.160 0.138 87	0.063 0.393 87	0.007 0.948 89	-0.112 0.006 87	-0.135 0.750 85	-0.212 0.015 86	0.067 0.004 86	0.049 0.004 86
	The brief given by the client is unclear	Pearson Correlation Sig. (2-tailed) N	0.178 0.093 90	0.311 0.003 90	-0.009 0.931 92	-0.001 0.991 92	0.273 0.007 96	0.035 0.738 94	0.160 0.138 87	0.063 0.393 87	0.007 0.948 89	-0.112 0.006 87	-0.135 0.750 85	-0.212 0.015 86	0.067 0.004 86	0.049 0.004 86
	Changes also to increase the engineering value	Pearson Correlation Sig. (2-tailed) N	-0.007 0.942 101	-0.011 0.912 101	0.020 0.842 101	0.020 0.842 105	0.135 0.097 107	0.072 0.458 107	0.008 0.936 97	-0.077 0.457 96	-0.138 0.170 96	-0.160 0.113 99	-0.106 0.273 106	-0.205 0.033 106	0.000 0.899 109	-0.073 0.448 109
	The design was realized under tight time constraints	Pearson Correlation Sig. (2-tailed) N	0.162 0.103 102	0.098 0.328 102	-0.161 0.098 102	-0.197 0.042 110	0.135 0.159 108	0.063 0.520 108	0.097 0.345 97	0.148 0.154 97	-0.054 0.589 101	-0.023 0.821 89	-0.102 0.291 110	-0.140 0.147 110	-0.109 0.267 110	-0.182 0.092 110
	There were modifications to the design once the project started	Pearson Correlation Sig. (2-tailed) N	0.172 0.027 105	0.032 0.212 105	0.203 0.026 105	0.784 0.004 109	0.027 0.904 113	0.073 0.609 111	0.017 0.869 105	0.063 0.335 105	0.086 0.472 105	0.315 0.539 104	0.214 0.934 103	0.358 0.475 112	0.067 0.284 112	0.049 0.264 113
	Design errors appear during the project	Pearson Correlation Sig. (2-tailed) N	0.157 0.110 105	0.211 0.030 105	0.226 0.792 106	0.003 0.296 110	0.100 0.001 113	0.315 0.024 111	0.238 0.024 100	0.092 0.017 100	0.005 0.364 100	0.007 0.961 104	-0.347 0.621 103	-0.156 0.600 112	-0.111 0.242 112	-0.156 0.100 113
Design mistakes are encountered in the project	Pearson Correlation Sig. (2-tailed) N	0.091 0.368 102	0.130 0.189 102	0.046 0.642 105	0.081 0.407 105	0.328 0.001 109	0.185 0.056 107	0.107 0.299 96	0.033 0.753 96	0.079 0.434 96	0.022 0.828 98	-0.062 0.524 106	-0.105 0.279 106	-0.130 0.216 109	-0.172 0.100 109	
The project has an outdated design	Pearson Correlation Sig. (2-tailed) N	0.173 0.081 96	0.154 0.135 96	-0.134 0.170 100	-0.074 0.463 101	0.214 0.023 104	-0.144 0.150 102	0.071 0.495 94	0.034 0.748 84	0.001 0.995 84	-0.058 0.573 95	-0.058 0.001 104	-0.362 0.535 104	-0.286 0.003 104	-0.307 0.002 104	
Information from any given source provided to designers is inadequate	Pearson Correlation Sig. (2-tailed) N	0.007 0.919 109	0.015 0.593 109	0.743 0.002 104	0.002 0.983 107	0.004 0.904 105	0.620 0.025 107	0.869 0.063 96	0.335 0.472 96	0.539 0.934 98	0.934 0.000 106	0.475 0.407 106	0.284 0.067 106	0.264 0.049 109	0.113 0.113 112	
Designer team is not involved during the construction phase	Pearson Correlation Sig. (2-tailed) N	0.182 0.062 103	0.237 0.016 103	-0.041 0.657 103	0.149 0.127 106	0.151 0.115 110	-0.042 0.669 108	0.082 0.558 98	0.073 0.906 98	0.013 0.306 102	-0.003 0.976 99	-0.043 0.185 102	-0.043 0.656 109	-0.324 0.001 110	-0.214 0.025 110	
There are discrepancies between contract documents in the project	Pearson Correlation Sig. (2-tailed) N	0.051 0.615 99	0.168 0.097 99	0.003 0.973 103	0.107 0.281 104	0.307 0.001 107	0.101 0.305 105	0.200 0.052 95	0.098 0.344 95	-0.068 0.518 98	-0.025 0.803 98	-0.150 0.123 107	-0.022 0.821 106	-0.201 0.038 107	-0.208 0.032 107	
There is a lack of awareness of regulations or requirements of local authorities	Pearson Correlation Sig. (2-tailed) N	0.275 0.005 103	0.263 0.007 103	-0.002 0.966 104	-0.002 0.005 111	0.050 0.005 109	0.419 0.111 108	0.202 0.58 98	0.472 0.102 100	0.701 0.555 102	0.000 0.057 111	-0.213 0.057 110	-0.250 0.028 111	-0.167 0.056 111	-0.103 0.010 112	
The project has incomplete drawings	Pearson Correlation Sig. (2-tailed) N	0.127 0.201 104	0.131 0.184 105	0.087 0.494 109	0.021 0.829 112	0.265 0.006 110	0.048 0.643 100	0.068 0.257 100	0.114 0.476 100	-0.073 0.799 104	-0.025 0.792 101	-0.131 0.168 111	-0.113 0.023 111	-0.180 0.057 112	-0.243 0.010 112	
There are requests to use available materials in the market	Pearson Correlation Sig. (2-tailed) N	-0.004 0.966 102	-0.069 0.488 102	0.085 0.385 104	-0.073 0.455 106	0.215 0.024 110	0.227 0.021 108	0.027 0.791 98	0.034 0.741 97	-0.021 0.836 102	0.118 0.252 110	0.011 0.909 110	-0.016 0.866 109	-0.034 0.722 110	0.043 0.656 111	
In the project alternative construction methods are used	Pearson Correlation Sig. (2-tailed) N	-0.070 0.496 98	-0.011 0.912 98	0.088 0.381 102	-0.059 0.491 102	0.062 0.524 106	0.139 0.160 104	0.059 0.438 94	0.059 0.571 94	-0.028 0.786 98	-0.028 0.201 98	-0.022 0.826 106	-0.022 0.546 106	-0.289 0.984 106	-0.073 0.455 106	
There are incomplete items and specifications in the project	Pearson Correlation Sig. (2-tailed) N	0.173 0.079 104	0.160 0.104 104	0.007 0.948 108	-0.070 0.470 108	0.277 0.003 112	0.003 0.971 110	0.010 0.920 99	-0.073 0.471 99	0.012 0.906 103	-0.078 0.436 102	-0.093 0.330 112	-0.129 0.177 112	-0.187 0.048 112	-0.243 0.023 113	
During the project the contractor requests or suggests improvements for the sustainability of the project	Pearson Correlation Sig. (2-tailed) N	0.067 0.441 105	0.024 0.807 105	0.083 0.381 106	-0.099 0.201 110	0.073 0.442 113	0.203 0.111 101	0.131 0.309 105	0.039 0.701 105	-0.085 0.386 103	0.025 0.865 103	0.031 0.746 112	-0.058 0.665 112	0.123 0.195 113	0.109 0.251 113	
There are inefficient working drawing details for the project	Pearson Correlation Sig. (2-tailed) N	0.154 0.290 105	0.099 0.314 105	0.028 0.771 109	-0.118 0.220 113	0.245 0.009 111	0.039 0.681 111	0.030 0.694 101	0.010 0.917 104	-0.089 0.369 104	-0.040 0.685 104	-0.123 0.195 112	-0.222 0.019 112	-0.239 0.011 113	-0.293 0.007 113	
There is a poor project organizational structure	Pearson Correlation Sig. (2-tailed) N	0.231 0.017 107	0.180 0.063 107	0.075 0.818 111	-0.113 0.239 115	0.290 0.002 113	0.129 0.175 102	0.097 0.332 102	0.017 0.867 106	-0.098 0.317 104	-0.001 0.991 104	-0.130 0.065 115	-0.157 0.065 115	-0.380 0.000 115	-0.363 0.000 115	
The project experienced unfavorable circumstances during construction	Pearson Correlation Sig. (2-tailed) N	0.110 0.262 105	0.097 0.325 105	-0.062 0.533 109	-0.013 0.891 113	0.386 0.000 111	0.167 0.100 102	0.243 0.013 102	0.048 0.145 105	0.056 0.572 105	0.164 0.062 104	-0.062 0.009 113	-0.305 0.518 113	-0.316 0.001 113	-0.366 0.001 113	
There is a lack of coordination and communication	Pearson Correlation Sig. (2-tailed) N	0.203 0.037 106	0.128 0.191 106	0.053 0.586 110	-0.046 0.638 110	0.386 0.006 114	0.058 0.597 112	0.053 0.397 102	0.007 0.845 102	0.074 0.504 104	0.066 0.504 104	-0.138 0.434 114	-0.049 0.604 114	-0.363 0.000 114	-0.302 0.001 114	
There are fragmentation/availability of information within the project	Pearson Correlation Sig. (2-tailed) N	0.018 0.104 104	0.013 0.104 104	0.379 0.108 108	0.158 0.108 112	0.000 0.110 110	0.589 0.110 101	0.138 0.101 101	0.699 0.101 103	0.810 0.103 103	0.174 0.103 112	0.142 0.112 112	0.883 0.112 112	0.002 0.112 112	0.000 0.112 112	
There are multiple not aligned schedules in the project	Pearson Correlation Sig. (2-tailed) N	0.278 0.004 107	0.260 0.007 107	-0.071 0.861 111	-0.116 0.225 111	0.269 0.004 111	-0.009 0.924 113	0.234 0.018 103	0.073 0.468 103	0.022 0.826 106	0.061 0.541 104	-0.211 0.024 115	-0.093 0.307 115	-0.382 0.000 115	-0.441 0.000 115	
There is an overlapping of design and construction phase	Pearson Correlation Sig. (2-tailed) N	0.075 0.425 105	0.123 0.213 105	0.044 0.621 109	0.019 0.842 113	0.311 0.000 111	0.097 0.047 110	0.049 0.339 100	0.048 0.626 100	0.048 0.064 104	0.142 0.151 103	-0.033 0.732 113	-0.033 0.683 113	-0.237 0.011 113	-0.187 0.048 113	
There are changes in the ground conditions during the project	Pearson Correlation Sig. (2-tailed) N	0.129 0.198 101	0.137 0.172 101	0.140 0.195 105	0.059 0.549 108	0.228 0.018 114	0.047 0.633 108	0.123 0.223 97	0.175 0.086 97	-0.101 0.317 103	0.080 0.429 103	-0.144 0.137 109	-0.072 0.463 109	-0.125 0.197 109	-0.122 0.208 109	
Changes in the site layout and/or access to it arise during the project	Pearson Correlation Sig. (2-tailed) N	0.125 0.189 106	0.111 0.255 107	0.068 0.473 111	-0.083 0.512 114	0.110 0.245 112	0.017 0.026 101	0.124 0.218 101	0.221 0.026 101	-0.115 0.244 105	-0.006 0.951 103	-0.152 0.106 114	-0.071 0.454 114	-0.079 0.412 114	-0.143 0.129 114	
There are differing site conditions during the project than planned	Pearson Correlation Sig. (2-tailed) N	0.192 0.050 105	0.142 0.150 105	-0.042 0.549 109	-0.030 0.684 113	0.121 0.702 115	0.149 0.205 111	0.222 0.136 103	0.059 0.026 106	-0.052 0.598 104	-0.078 0.434 106	-0.039 0.679 114	-0.039 0.834 114	-0.116 0.222 114	-0.153 0.105 114	
There are changes in economic conditions during the project	Pearson Correlation Sig. (2-tailed) N	0.277 0.102 102	0.088 0.106 102	0.267 0.106 106	0.515 0.106 109	0.019 0.109 108	0.182 0.108 108	0.485 0.97 97	0.816 0.07 101	0.164 0.101 101	0.100 0.101 109	0.812 0.106 109	0.166 0.106 109	0.005 0.109 109	0.798 0.109 109	
Changes arise during the project regarding government policies/laws	Pearson Correlation Sig. (2-tailed) N	0.046 0.652 100	0.066 0.093 100	0.109 0.270 104	-0.087 0.379 107	0.312 0.001 107	0.202 0.039 106	0.087 0.397 96	0.153 0.138 96	-0.076 0.453 101						

Appendix H – Expert Session Protocol

The expert session protocol was conducted via Microsoft Teams and Microsoft Forms, on the 24th of March 2022. The expert session was attended by four experts in the area of planning within DPR Construction, see Figure 27. The expert session was set-up in three main steps in which firstly a presentation of the research was carried out, following a survey was delivered and completed by each participant separately, and lastly, the discussion session took place. In the expert session, the proposed suggestions and the proposed implementation roadmap were validated. The complete expert session lasted 120 minutes.

The protocol followed for expert session was as follows:

1. Introduction and Overview of research and correlation analysis results. *(Duration: ≈ 20 minutes)*
2. Validation of proposed suggestions: Individual Survey to gather individuals' opinion on each suggestion in an objective way without being influenced by the opinion of the rest of the experts.
3. Validation of proposed suggestions: Discussion on each of the Proposed Suggestions. One by one discussion of all proposed suggestions. *(Duration: ≈ 35 minutes)*
4. Validation of proposed conceptual framework: Presenting and explaining the Implementation Roadmap. Discussion based on following questions. *(Duration: ≈ 50 minutes)*
 - *Do you think the proposed roadmap is valid and applicable in the company?*
 - *Which steps/suggestions are not clear from the implementation roadmap?*
 - *What should be changed or restructured from the proposed implementation to make it more applicable?*
 - *Do you think the current working culture of DPR Construction is suitable for implementing this roadmap?*
 - *The suggestions provided in the roadmap are not new or unknown, do you believe that they are being used among practitioners? If not, why?*

Appendix I – Survey Expert Session

Validation of Research Thesis

In the next sections you will find different questions about the research that was presented moments ago. Please feel free to respond at these questions honestly, and not leave any detail behind.

Thank you for your help.



* Required

Personal Details

1

Name and Surname *

Enter your answer

2

What is your current role in company? *

Enter your answer

3

How many years of experience do you have in total? *

Enter your answer

4

How many years of experience in this area of work? *

Enter your answer

Next

* Required

Opinion about Proposed Suggestions

In this section it must be rated how much you agree or disagree with the efficacy of each proposed suggestion.

5

Proposed Suggestions for Phase 1 *

Flexibility Recourses in Practice: the Implementation

Flexibility Recourses which decrease Design Change Causes

Implementation - Phase 1	Defragmentation of Information	Multi-disciplinary Teams
	Prioritize the availability of information for all parties	Involvement of all parties since project starts
	Diminish fragmentation of information by simplifying its access and availability	Implementing a work culture in the company that prioritizes team-working
	Standardization of organized storing of information	Promotion of team-building activities
	Send weekly reports with project status to every project team member, trades, subcontracts, client, etc.	Encourage practitioners to establish good relations with third parties in the team project

	Totally Agree	Agree	Neutral	Disagree	Totally Disagree
Prioritize the availability of information for all parties	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Diminish Fragmentation of information by simplifying its access and availability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Standardized format for organizing project's information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Weekly reports with projects status sent to every party involved in project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Involvement of all parties since project starts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Implementing a work culture in the company that prioritizes team-working	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Promotion of team-building activities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Encourage practitioners to establish good relations with third parties in the project team	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6

Do you have any practical objections towards any of these suggestions? *

Enter your answer

7

Do you believe there is any added value from these suggestions? *

Enter your answer

8

Any additional suggestion to add or complement an existent suggestion? *

Enter your answer

9

Proposed Suggestion for Phase 2 *

Flexibility Recourses which increase Design Change Causes	
Implementation - Phase 2	Combination of Paradigms
	Balance the use of flexibility recourses with traditional project management.
	Flexible recourses used as measures for managing design changes, not design change causes
	Use traditional methods in planning to control the appearance of design change causes
	Provide training workshops on flexibility recourses and flexible practices
Breaking the stigma	
Raise awareness on flexibility recourses and flexible practices	
Incentivize workers to search for innovation and better strategies to reach objectives.	
Sharing information on projects which implemented flexibility recourses and their lessons learned	
Company support by generating trials of flexibility use on projects to gain acceptance of these practices	

	Totally Agree	Agree	Neutral	Disagree	Totally Disagree
Balance the use of flexibility recourses with traditional project management.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flexible recourses used as measures for managing design changes, not design change causes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Use traditional methods in planning to control the appearance of design change causes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Flexible recourses used as measures for managing design changes, not design change causes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Use traditional methods in planning to control the appearance of design change causes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provide training workshops on flexibility recourses and flexible practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Raise awareness on flexibility recourses and flexible practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Incentivize workers to search for innovation and better strategies to reach objectives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sharing information on projects which implemented flexibility recourses and their lessons learned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Company support by generating trials of flexibility use on projects to gain acceptance of these practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10

Do you have any practical objections towards any of these suggestions? *

Enter your answer

11

Do you believe there is any added value from these suggestions? *

Enter your answer

12

Any additional suggestion to add or complement an existent suggestion? *

Enter your answer

13

Proposed Suggestions for Phase 3 *

Implementation - Phase 3

Flexibility Recourses without a logical causality

Dealing with secondary effects	Future Steps
These effects should be incorporated as external risks in order to be able to manage them correctly.	Continue researching into this topic after having applied the first two phases of the implementation
Flexibility Recourses are recommended to be used to manage the change itself but not its causes.	Further research the causality behind this relationships to understand it completely

	Totally Agree	Agree	Neutral	Disagree	Totally Disagree
These effects should be incorporated as external risks in order to be able to manage them correctly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flexibility Recourses are recommended to be used to manage the change itself but not its causes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Continue researching into this topic after having applied the first two phases of the implementation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Further research the causality behind this relationships to understand it completely	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14

Do you believe there is any added value from these suggestions? *

Enter your answer

15

Do you have any practical objections towards any of these suggestions? *

Enter your answer

* Required

Further Comments

17

Any further comments? Please let me know *

Enter your answer

Back

Next

Final Words

Thank you so much for being part of this expert session. Your help is invaluable for my research.

Back

Submit